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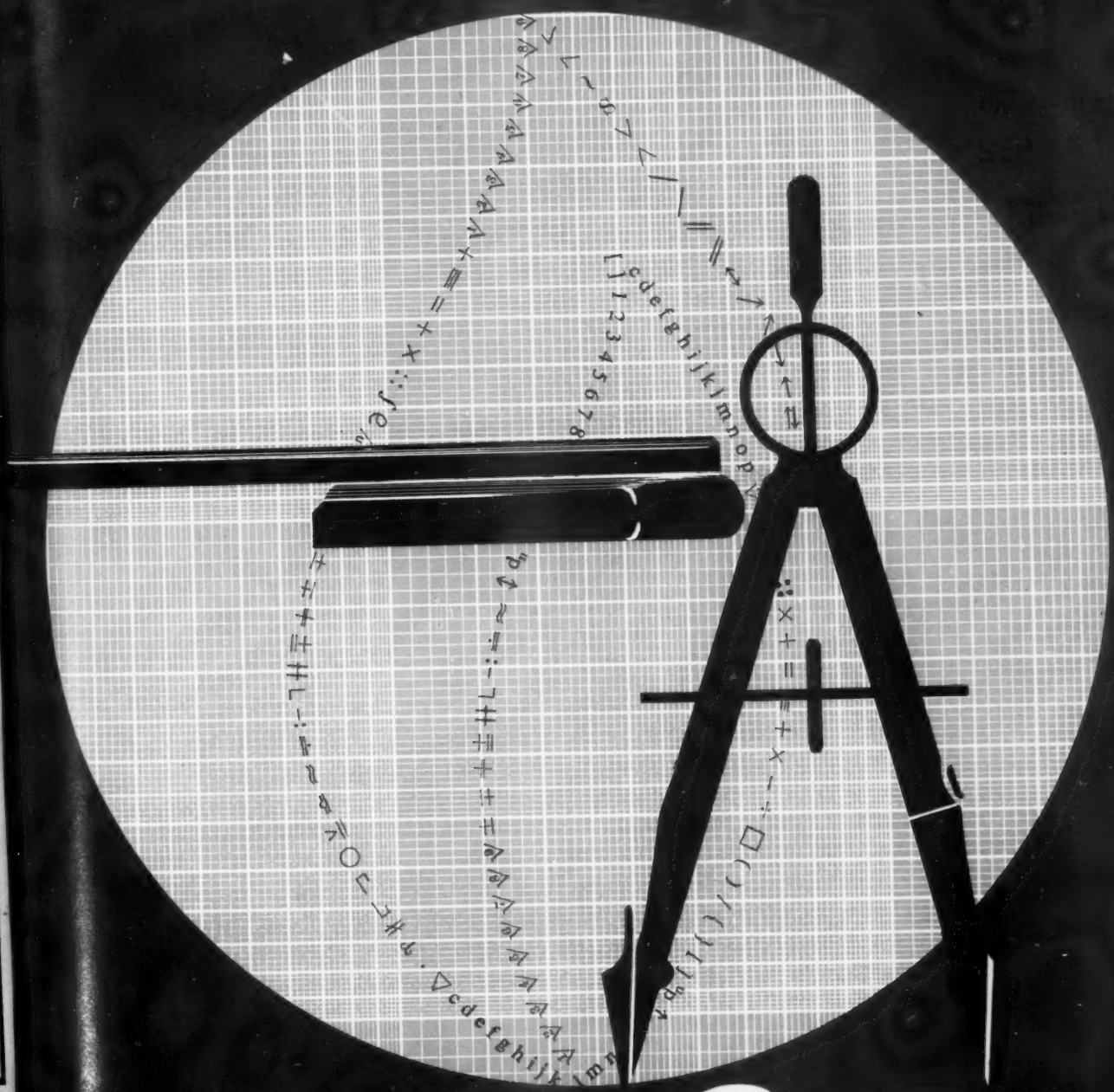
THE MAGAZINE OF GAS DISTRIBUTION

AUGUST 15, 1960



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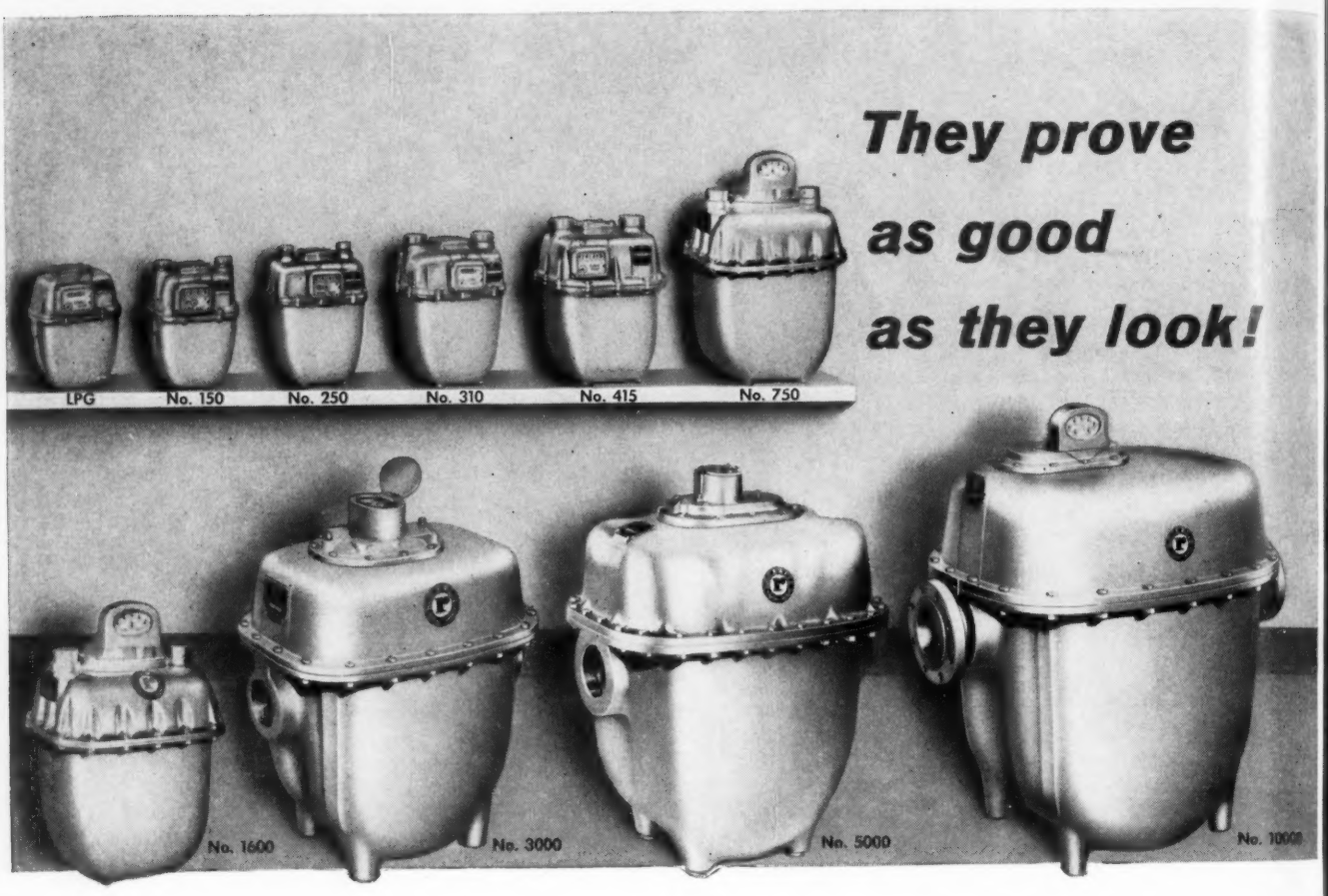

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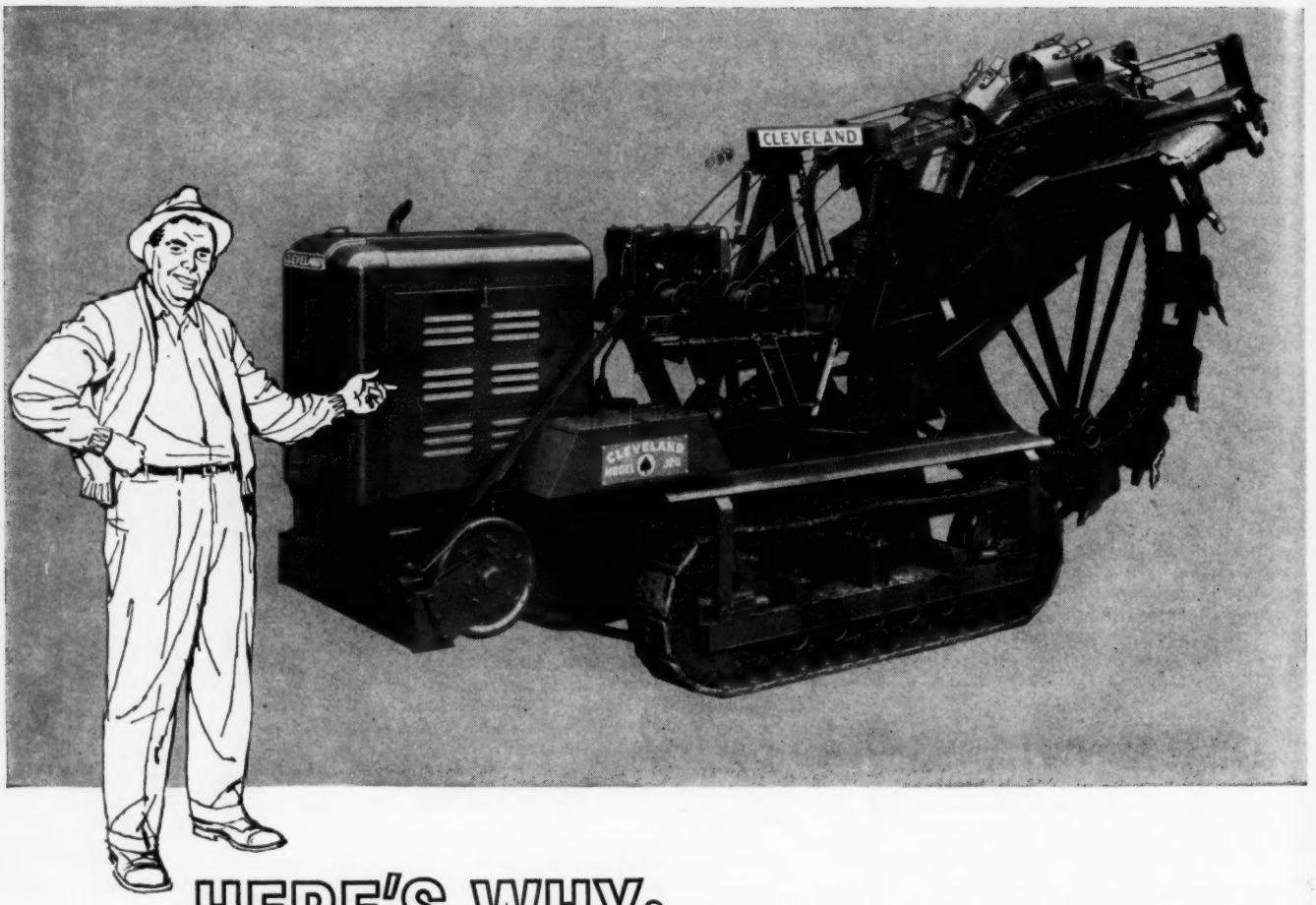

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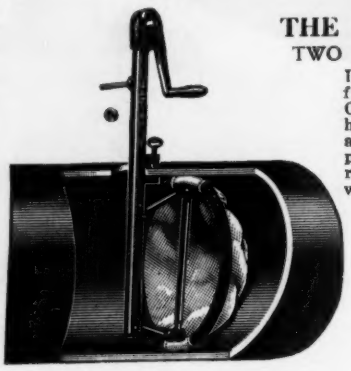

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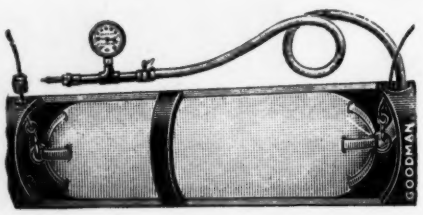

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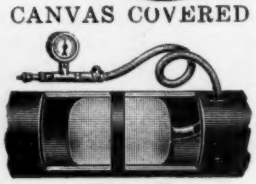

Type C

For the present, we have discontinued the manufacture of all types of bags except Type "B" Plain Rubber (medium weight) and Type "C" Canvas Covered Bags.

Type "C" for use in mains coated with tar or oil and wherever a plain rubber bag would not hold. This canvas-covered bag consists of an inner bag of fine quality rubber, strong and expansible, encased in a cover made of best quality U. S. Army duck. **Gauge of Rubber and strength of duck suited to each size.** Bags correctly fashioned and covers finely tailored insure a snug fit and a good shut-off when the bag is inflated in the pipe. Fitted with tire valve, nipple, hose clamp and thumb screw. **Inflate** as you would a tire. **To deflate** pull out the valve.

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A valuable aid to have on hand to bandage up breaks in mains and services. Repairs made this way will hold for long periods if necessary. Bandage with Soap Tape and cover with Binding Tape Strips 2", 4", 6", 8".

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Texas utilities contractor reports:

"OUR 774 CUTS 25-200% MORE TRENCH THAN DITCHERS WITH MECHANICAL TRANSMISSIONS"

"We know for a fact our Barber-Greene 774 Ditcher with dual-range Hydra-Crowd transmission cuts 25 to 200% more ditch daily than mechanical transmission ditchers we've used," says H. W. McCurley, of Pearson & McCurley, Beaumont, Texas, utilities contractors.

"Actually the 774 revolutionizes ditcher design with a hydraulic control system that gives the operator fingertip control of forward crowding speeds, boom hoist, discharge conveyor drive . . . all independent of wheel digging speeds. And our operator sure likes the instant dialing of maximum crowding speed for any ground condition.

NO PARTS REPLACEMENT—"In ditching 36,000 feet, we've had no parts replacement . . . never changed digging teeth, side cutters or gumbo cutting lips on fingerback buckets," he recalls.

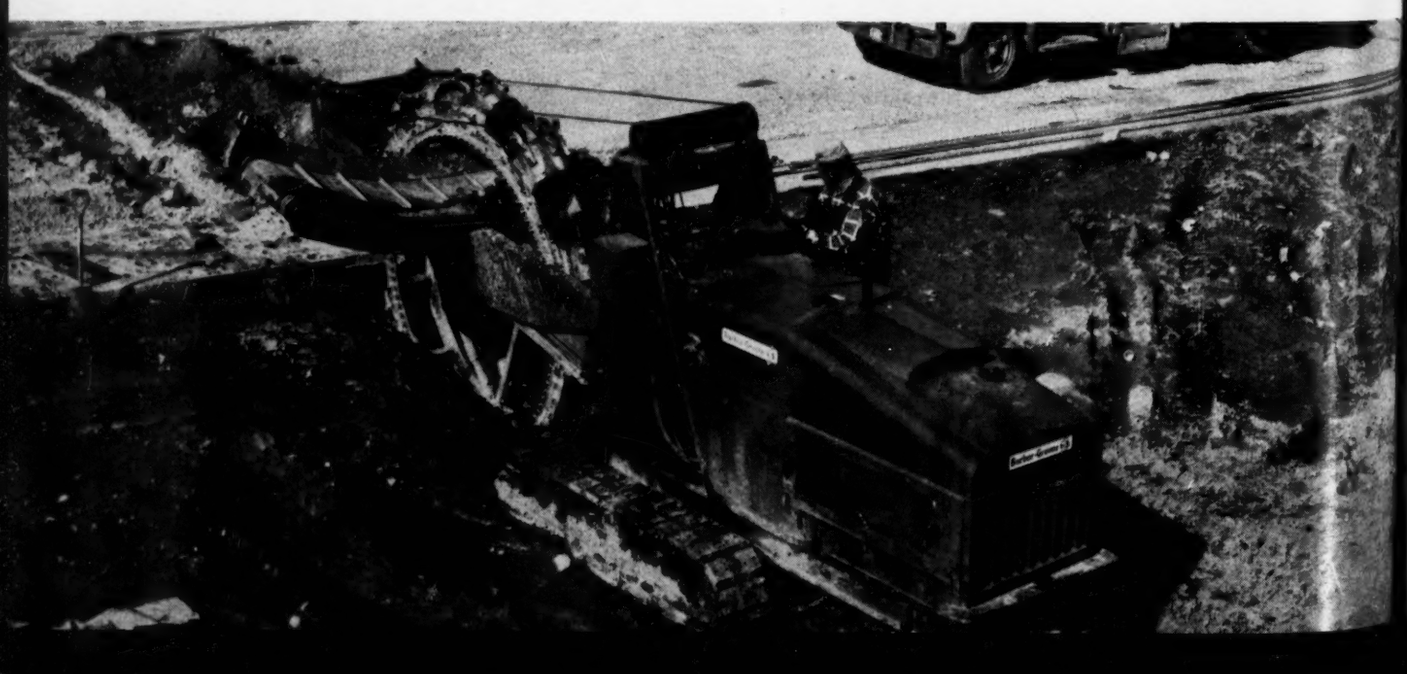
This Texas firm bought its 774 after renting one from a contractor. Your Barber-Greene Distributor will take you to a job and show you the ditcher you are interested in so you'll get all the facts. Call him today.

Midwest utility company

OWNS FLEET OF OVER 25 BARBER-GREENES

This Barber-Greene dug in record time the street mains and over 300 services in one subdivision, keeping well ahead of the crew that was welding, wrapping and lowering in. Owned by a major midwestern gas utility, the Model 773 shown below is only one of the more than 25 Barber-Greene Ditchers in their fleet.

For close quarter operation, Barber-Greene's 772, identical with the 773 except for narrower track gauge and pad width, works within 19″ of side obstructions. All three utility ditchers have dual-range Hydra-Crowd transmission, exclusive digging wheel drive with fully guarded chains, automatic overload protection, shock-absorbing flexible drawbar, hydraulically driven spoil conveyor with rubber-impact rollers, and fewest wearing parts for minimum maintenance. Model 774 is available with 5½ or 7′ wheels and cuts from 18-30″ wide. Models 773 and 772 trench to 5½′ deep and 10-24″ wide.



On jobs in Beaumont and Orange, Texas, installing pipe from 8" to 16", Pearson & McCurley's 774 with 5½-ft. wheel dug up to 2,500-ft. daily in tough gulf coast gumbo. "Has plenty of reserve to dig far beyond our daily needs," says Mr. McCurley.

Rubber-tired or crawler mounted Barber-Greene Vertical Boom Ditchers cut lowest cost trench from 5½" to 24" wide and to 7' deep. Model 705-B, shown, digs to 4'8" deep.

Manufacturer of the only modern ditcher line

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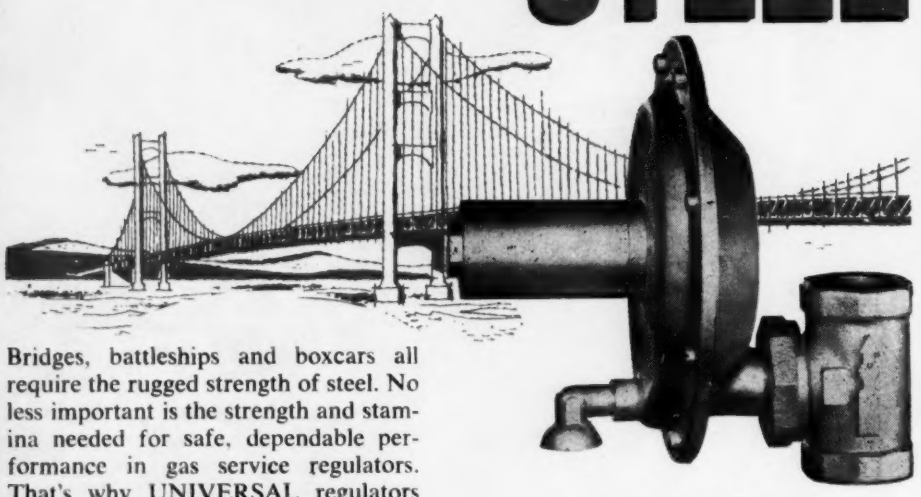
the strength of **STEEL**



Bridges, battleships and boxcars all require the rugged strength of steel. No less important is the strength and stamina needed for safe, dependable performance in gas service regulators. That's why UNIVERSAL regulators are made exclusively of steel. They are shock resistant, lighter in weight and thoroughly dependable.

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UNIVERSAL GAS SERVICE REGULATORS

★ The original vertical diaphragm prevents water accumulation ... no freezing, no internal parts rusting.

★ Every regulator "operation tested" at factory and set at desired outlet pressure.

★ Vital internal parts are made of bronze, stainless steel and aluminum for best corrosion resistance.

★ Once installed, regulators cannot be rotated to allow water, dust or other foreign particles to accumulate and disrupt service.

★ Engineering design and construction afford many exclusive maintenance and service advantages.

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*Gum-resistant ring Specially compounded of friction-free inert carbon-graphite

*Large-Profile Stud offers greater contact area

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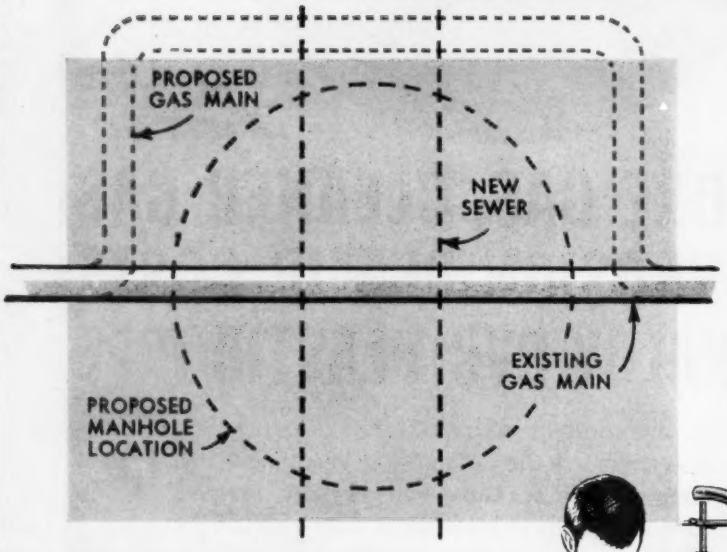
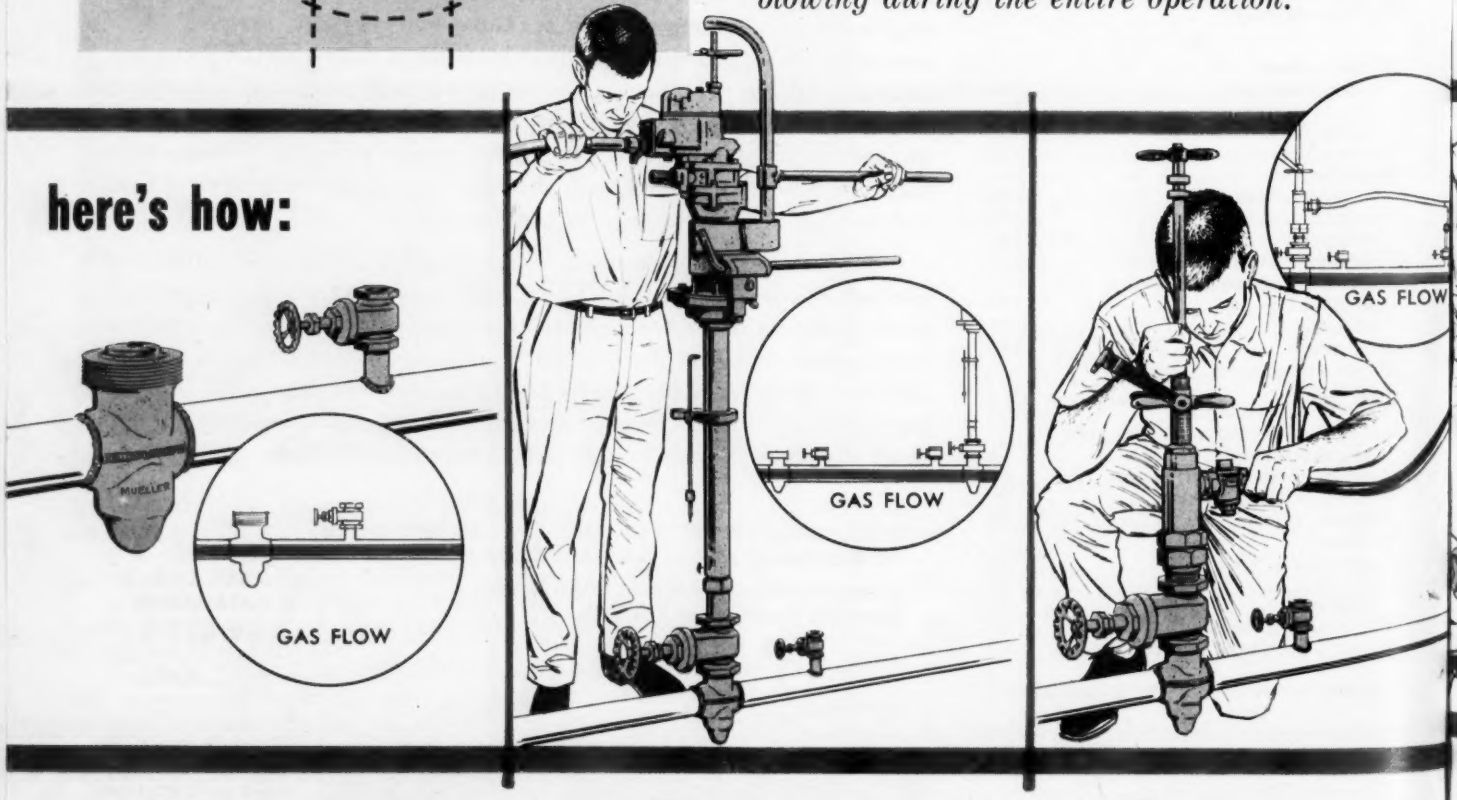


■ Recently a new sewer trunk line and manhole installation posed a tough line relocation problem for a gas utility company. Serving an industrial and residential area, service could not be interrupted during relocation of the line.

This schematic diagram of the problem and the step by step illustrations show how the line was relocated with Mueller No-Blo Method Line Stopper Fittings and Equipment . . . *without interrupting service* and *without gas blowing during the entire operation.*

here's how:



STEP 1 ATTACH FITTINGS

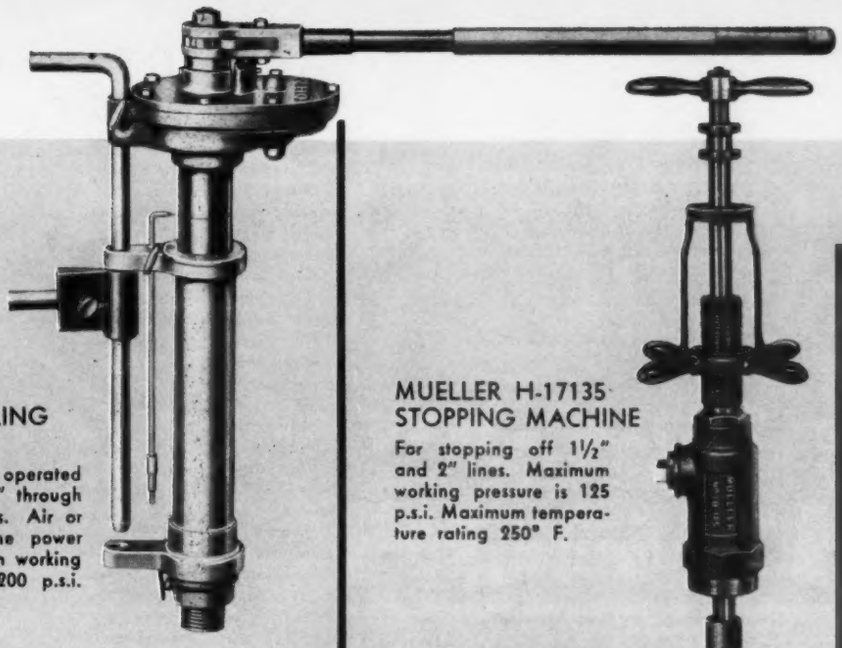
Weld Mueller Line Stopper Fittings to main on each side of section to be relocated. Weld Save-A-Valve Drilling Nipples to line providing by-pass and purging connections. Attach gate valves to drilling nipples.

STEP 2 DRILL MAIN

Attach special Mueller gate valve to stopper fitting. Attach DH-2 Drilling Machine (or D-4 Drilling Machine) to gate valve. Make cut, retract drill, close gate valve and remove drilling machine. Repeat cutting operation in second line stopper fitting and Save-A-Valve Drilling Nipples.

STEP 3 CONNECT BY-PASS

Attach line stopper to H-17135 Stopping Machine and attach Machine to gate valve. Connect by-pass line between the H-17135 Stopping Machines. Purge by-pass, then start flow through the by-pass line.



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For stopping off 1½" and 2" lines. Maximum working pressure is 125 p.s.i. Maximum temperature rating 250° F.

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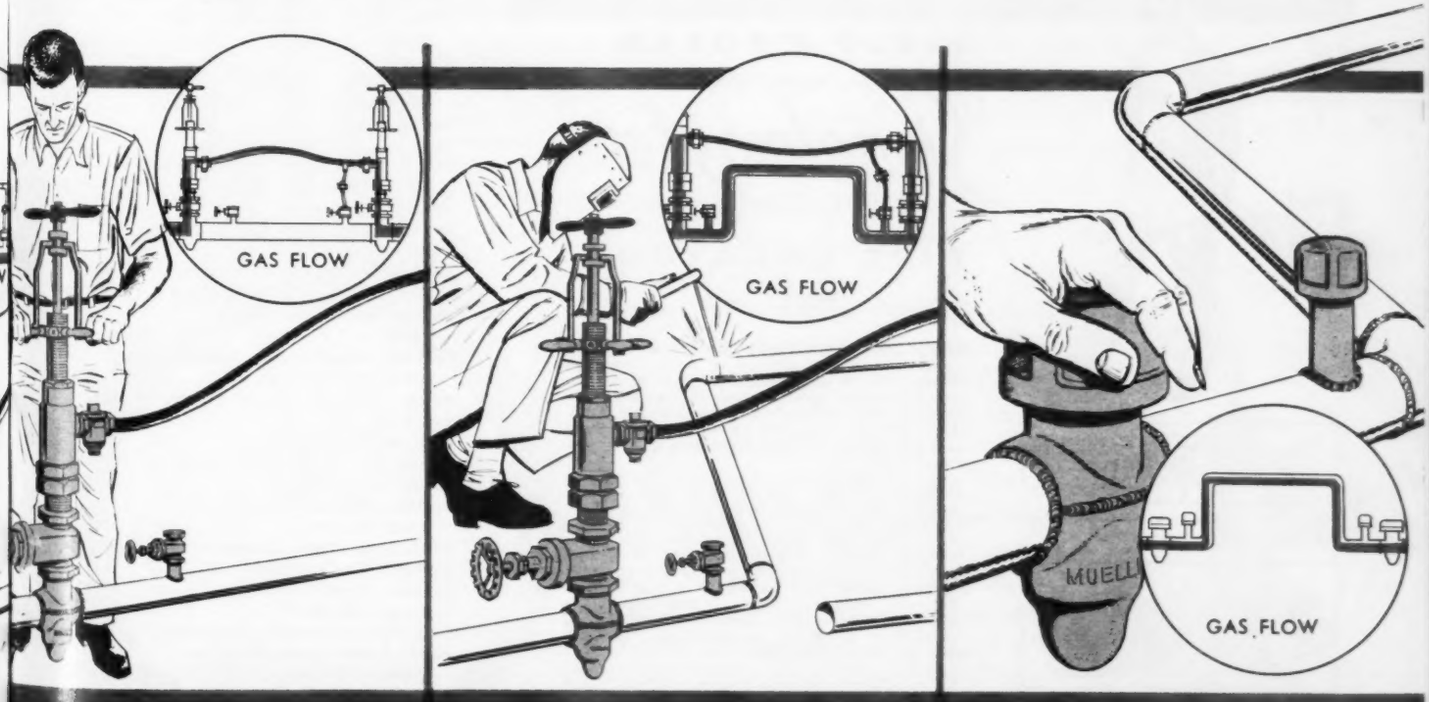

STEP 4 STOP-OFF

Open gate valve on upstream stopper fitting, insert and expand stopper. Repeat stop-off operation on downstream stopper fitting. Section is now isolated.

STEP 5 RELOCATE MAIN

With by-pass line maintaining flow of gas without interruption or shut-down, the isolated section can be removed and relocated. Test new welds before activating new section.

STEP 6 ACTIVATE MAIN

Purge isolated main section after welds have cooled. Using Unit #1 Stopping Machine, remove line stopper in downstream fitting and close gate valve. Then remove line stopper fitting in upstream fitting. Main section is now in operation. Remove by-pass. Plug and cap line stopper fittings and drilling nipples.

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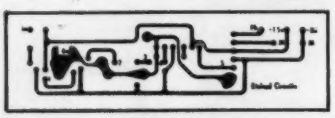

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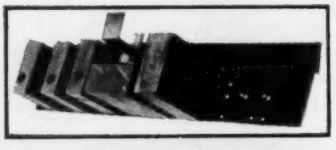

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PUNCH 'em!

For taking services off mains. A quick, safe, steel (shell casting) welding tee that incorporates in each tee a punch and positive shut-off. Does away entirely with drill devices. We also have a model threaded at the base to screw into the saddle.

Punches. ¼", 5/16" and ⅜" diameter, recommended for 5/16" (or thinner) pipe wall thickness. ½" diameter, restricted to use on ¼" wall thickness or thinner.

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← Four small guides which hold punch to its true axis.

Both sizes made have 1" base. Side outlet can be furnished ¾" or 1", end beveled for welding, standard pipe size, either threaded, or smooth for compression coupling. Or outlet can be internally threaded for ½" pipe size.

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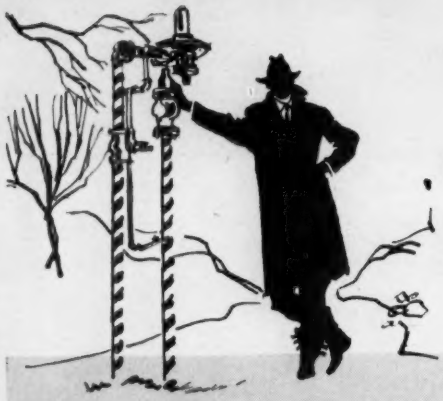
SKINNER-SEAL PUNCH-IT TEE



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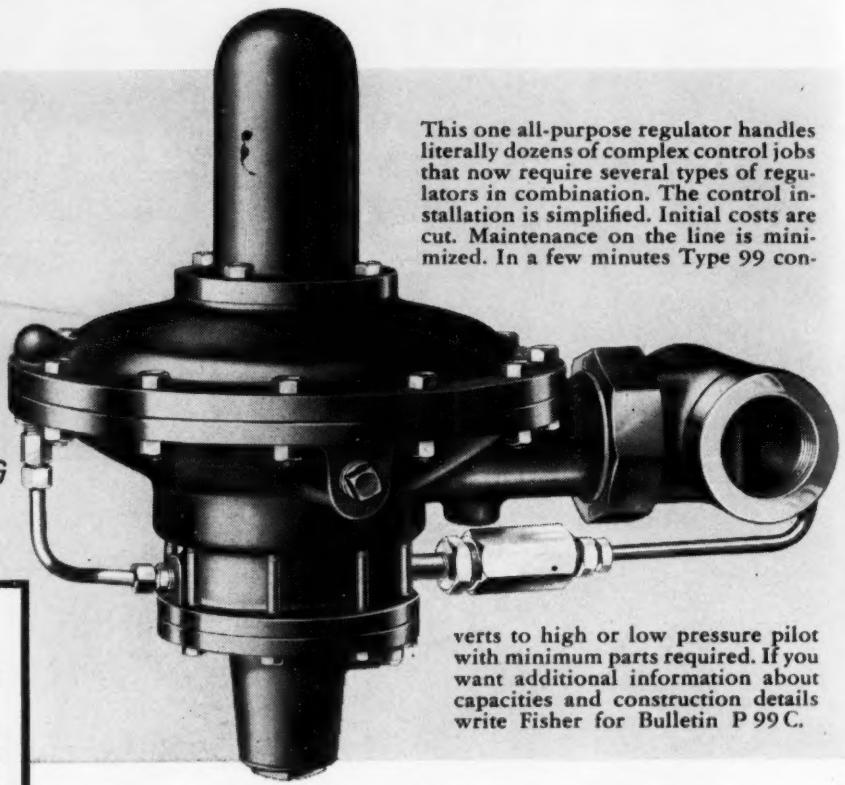

This one all-purpose regulator handles literally dozens of complex control jobs that now require several types of regulators in combination. The control installation is simplified. Initial costs are cut. Maintenance on the line is minimized. In a few minutes Type 99 converts to high or low pressure pilot with minimum parts required. If you want additional information about capacities and construction details write Fisher for Bulletin P 99 C.

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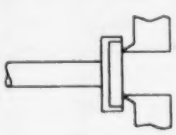
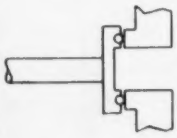
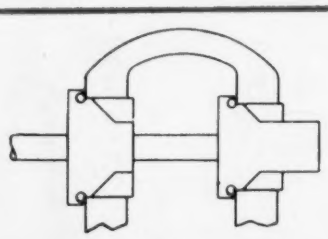


⅛" Composition Disc Single Port. Max. Inlet 250 psi. 1⅛" Composition Disc Single Port. Max. Inlet 150 psi.

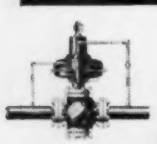


⅛" "O" Ring Single Port. Max. Differential 250 psi. 1⅛" "O" Ring Single Port. Max. Differential 250 psi. (with heavy main spring) 2" "O" Ring Single Port. Max. Differential 40 psi.



2" "O" Ring Double Port. Max. Differential 100 psi.

1. **The factory pre-set spring provides powerful lock-off action.**
2. **Large, effective area of main diaphragm in combination with relay pilot assures trouble-free accuracy.**
3. **It is only a matter of minutes and a minimum of parts to convert to high or low pressure pilot.**
4. **2" threaded or flanged inlet and outlet. Standard hi-tensile iron body for up to 150 PSI inlet, XH or bronze body for up to 250 PSI inlet.**
5. **Composition valve disc assures tight shutoff on zero flow and excellent regulation from low flow to maximum capacity.**



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SINCE 1880

Gas Distribution Line Flow Calculations

(For lines operating at pressures over 1 psig)

The following method of computing the flow of gas in distribution lines operating at pressures over 1 psig, and up to 100 psig inlet pressure, is based on the Spitzglass Formula for pressures over 1 psig. This formula is:

$$Q = 4830K\left(\frac{Pa}{SL}\right)^{1/2}$$

Where:

Q = Flow per hour in cu ft of gas at 14.73 psia and 60 F.
P = Pressure drop between terminals in psig.
a = Average pressure in line, psia. (Absolute initial pressure minus half the pressure drop).
S = Specific gravity of gas. (Air = 1.0).
L = Length of pipe in feet.
d = Internal diameter of pipe in inches.

$$K = \left(\frac{d^5}{1 + \frac{3.6}{d} + 0.03d}\right)^{1/2}$$

To arrive at the factors shown in the tables and graphs, the following formulas were used:

$$AA = 4830\,K\left(\frac{.5 \times (1 + 14.4 - .25)}{.65 \times 2000}\right)^{1/2}$$

$$BB = \left(\frac{Pa}{.5 \times (1 + 14.4 - .25)}\right)^{1/4}$$

$$C = \left(\frac{2000}{L}\right)^{1/2}$$

Calculations have been reduced to a practical form by the use of tables and graphs, where the hourly rate of flow, Q, is based on 0.65 specific gravity, 14.73 psia base pressure, temperature of 60 F, and barometer of 14.4 psia.

In making calculations in this section, the various factors used are given in tables and graphs as follows:

Factor AA: given in table in this section.

Factor BB: given in two graphs in this section.

Factor C: given in table in preceding section.

Where specific gravity differs from 0.65, correction factors for other specific gravities are used to modify the value of Q. These factors are given in the Specific Gravity Factor Tables in the preceding section.

To Find Hourly Rate of Flow

I. Where all gas is fed from one end of line and discharged at other end. $Q = AA \times BB \times C$

Example: Find hourly capacity of a 6-in. line, 800 ft long, with inlet pressure of 30 psig and pressure drop of 5 psig.

Solution: $25{,}100 \times 5.27 \times 1.58 = 208{,}997.66$ cu ft per hr.

II. Where conditions are not the same as outlined under (I) above, factors may be applied for different "cases," as outlined in the following section for calculating flow at pressures under 1 psi. These factors are:

Where gas is fed from one end of line and discharged at intervals along the line, use Factor "D" (= 1.7), and $\mathbf{Q = AA \times BB \times C \times D}$

Where gas is fed from both ends of line and discharged at intervals along the line, use Factor "E" (= 4.8), and $\mathbf{Q = AA \times BB \times C \times E}$

Where gas is fed from both ends of line and middle of line and discharged at intervals along the line, use Factor "F" (= 13.6), and $\mathbf{Q = AA \times BB \times C \times F}$

(For explanation of Factors D, E, and F, see chart on page 24 of this Handbook, entitled "Factors to Apply to Low Pressure Formulas Under Varying Conditions to Obtain Gas Delivery Quantities.)

III. Where conditions are such that deliveries from the line are made at different points along the line that are not equally spaced and that do not deliver equal volumes, it is necessary to separate the line into sections between such points of delivery and calculate flow for each section, using the formula outlined under (I) above.

To Find Pipe Diameter Required

Formula: $AA = \dfrac{Q}{BB \times C}$

Example: Find pipe diameter required to deliver 10,000 cu ft per hour for distance of 1000 ft at inlet pressure of 20 psig and pressure drop of 3 psig.

Solution: $\dfrac{10{,}000}{3.61 \times 1.41} = \dfrac{10{,}000}{5.0901}$ $AA = 1964.6$

From Table of "AA" Factors, a 2½-in. pipe would be required.

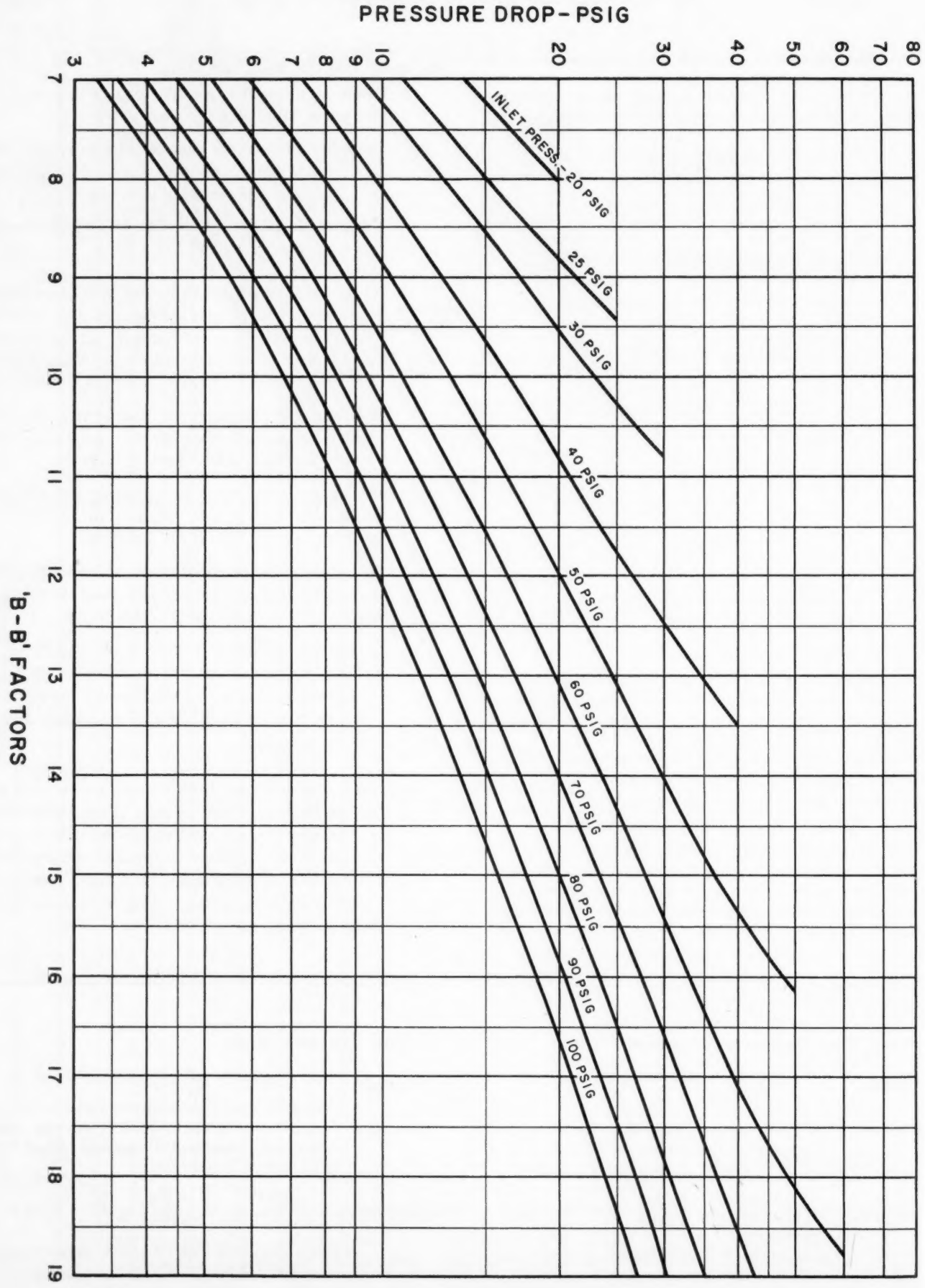
To Find Pressure Drop

Formula: $BB = \dfrac{Q}{AA \times C}$

Example: Find pressure drop in 1800 ft of 4-in. pipe, when inlet pressure is 20 psig and rate of flow is 20,000 cu ft per hour.

Solution: $\dfrac{20{,}000}{8460 \times 1.05} = \dfrac{20{,}000}{8883}$ $BB = 2.2514$

From Graph of "BB" Factors, pressure drop would be 1.4 psi.


PRESSURE DROP - PSIG
3
4
5
6
7
8
9
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20
30
40
50
60
70
80
7
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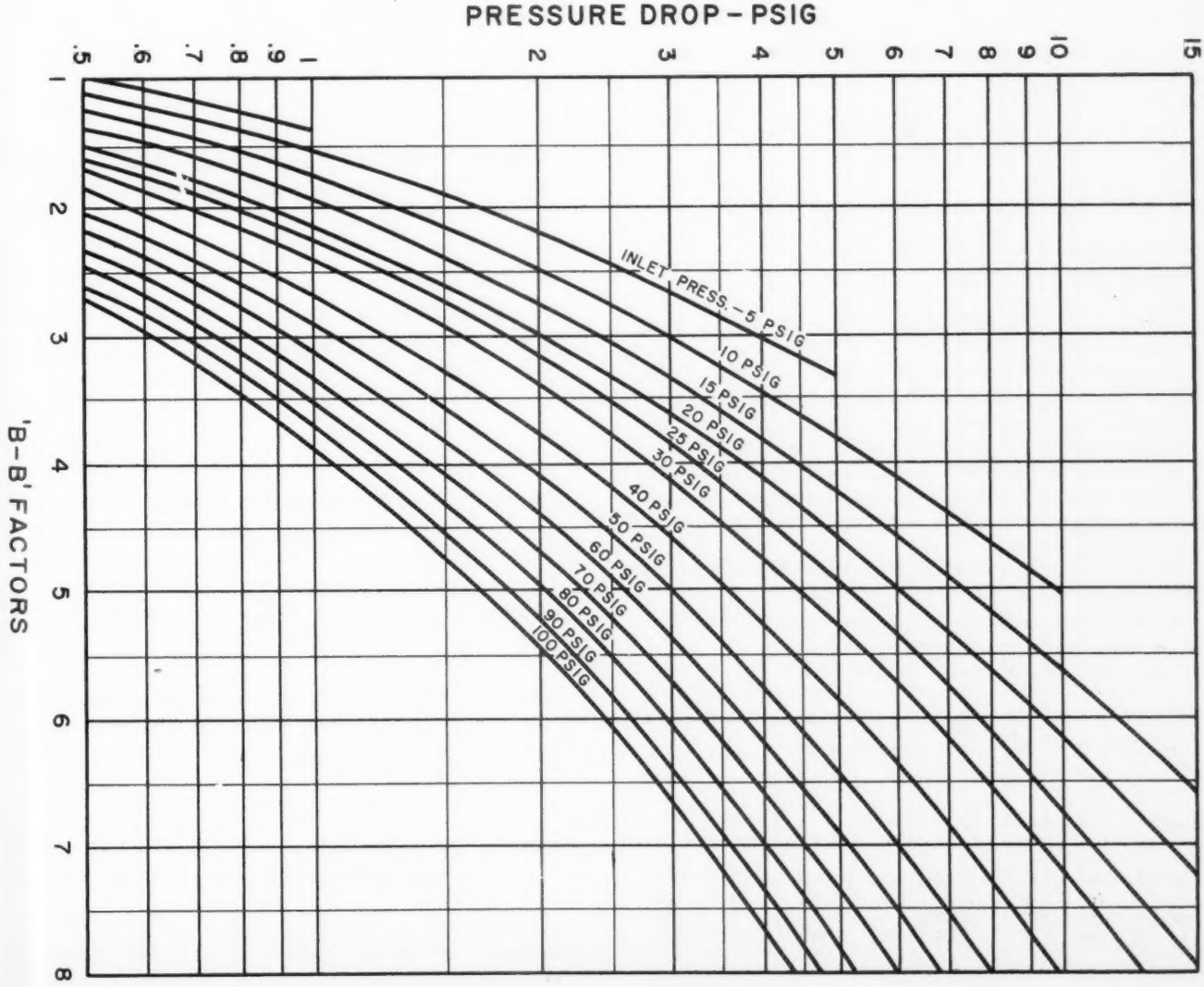
9
10
11
12
13
14
15
16
17
18
19
'B-B' FACTORS
INLET PRESS. - 20 PSIG
25 PSIG
30 PSIG
40 PSIG
50 PSIG
60 PSIG
70 PSIG
80 PSIG
90 PSIG
100 PSIG

'B-B' FACTORS

Table of "AA" Factors

(Standard Steel Pipe data except when starred (*) to indicate cast iron pipe)

Nominal Size Pipe (Inches)	Internal Diameter (Inches)	"AA"	Nominal Size Pipe (Inches)	Internal Diameter (Inches)	"AA"	Nominal Size Pipe (Inches)	Internal Diameter (Inches)	"AA"
1	1.049	196	*6	6.040	24,800	14	13.250	182,000
1¼	1.380	432	6	6.065	25,100	15	14.250	218,000
1½	1.610	670	*6	6.200	26,500	16	15.250	257,000
*2	1.875	1,030	8	8.071	52,500	16	15.375	263,000
2	2.067	1,350	*8	8.150	53,800	16	15.500	268,000
2½	2.469	2,220	10	10.020	91,000	*16	16.160	296,000
*3	3.020	3,870	*10	10.120	93,200	18	17.250	347,000
3	3.068	4,030	10	10.136	93,600	18	17.375	353,000
3½	3.548	5,980	10	10.192	94,900	18	17.500	359,000
*4	4.000	8,300	12	11.500	128,000	20	19.250	451,000
4	4.026	8,460	12	12.090	145,000	20	19.375	458,000
4½	4.506	11,400	*12	12.120	146,000	20	19.500	465,000
5	5.047	15,400	12	12.188	148,000	*20	20.240	508,000



Gas Distribution Line Flow Calculations

(For Lines Operating at Average Pressures Under 1 psi)

The following method of computing flow of gas in distribution lines at average pressures under 1 psi is based on the Spitzglass Formula for pressures under 1 psi. This formula is:

$$Q = 3550\,K\left(\frac{h}{SL}\right)^{1/2}$$

Where

Q = Flow per hour in cu ft of gas at 14.73 psia and 60 F.
H = Pressure drop in inches of water column.
S = Specific gravity of gas. Air = 1.0
L = Length of pipe in feet.
d = Internal diameter of pipe in inches.

$$K = \left(\frac{d^5}{1 + \frac{3.6}{d} + 0.03d}\right)^{1/2}$$

To arrive at the factors shown in the tables, the following formulas were used:

$$A = 3550\,K\left(\frac{.1}{.65 \times 2000}\right)^{1/2}$$

$$B = \left(\frac{h}{.1}\right)^{1/2}$$

$$C = \left(\frac{2000}{L}\right)^{1/2}$$

Calculations have been reduced to a practical form by the use of tables in which the hourly flow rate, Q, is based on a specific gravity of 0.65, 14.73 psia base pressure, and 60 F temperature. Tables of Factors for A, B, C, D, E, and F, as used in the examples, are given on page 22.

Where specific gravity of the gas being distributed differs from the 0.65 sp. gr. used in developing the tables, the value of Q may be modified to obtain greater accuracy by applying the proper factor from the table of Specific Gravity Factors given below.

When finding the rate of flow, multiply the calculated Q by the proper factor.

When finding required pipe diameter or pressure drop, divide the given Q by the proper factor.

The factor is determined by the formula:

$$\text{Sp. Gr. factor} = \left(\frac{.65}{\text{Sp. Gr.}}\right)^{1/2}$$

Specific Gravity	Factor	Specific Gravity	Factor	Specific Gravity	Factor	Specific Gravity	Factor
.60	1.041	.64	1.008	.68	.978	.72	.950
.61	1.032	.65	1.000	.69	.971	.73	.944
.62	1.024	.66	.992	.70	.964	.74	.937
.63	1.016	.67	.985	.71	.957	.75	.931

To Find Hourly Rate of Flow

CASE 1-A. All gas fed from one end of line and discharged at other end.

$$Q = A \times B \times C$$

Example: Find hourly capacity of a 4-in. line, 500 ft long, with pressure drop of 1.0-in. w.c.

Solution: $715 \times 3.16 \times 2.00 = 4519$ cu ft per hour

---

CASE 1-B. All gas fed from one end of line and discharged at intervals along the line.

$$Q = A \times B \times C \times D$$

Example: Find hourly capacity of a 6-in. line, 400 ft long, with pressure drop of 1.5-in. w.c.

Solution: $2120 \times 3.87 \times 2.24 \times 1.7 = 14{,}009$ cu ft/hr

---

CASE 1-C. Gas fed from both ends of line and discharged at intervals along the line.

$$Q = A \times B \times C \times E$$

Example: Find hourly capacity of a 3-in. line, 800 ft long, with pressure drop of 0.7-in. w.c.

Solution: $341 \times 2.65 \times 1.58 \times 4.8 = 6853$ cu ft per hr

---

CASE 1-D. Gas fed from both ends and middle of line and discharged at intervals along the line.

$$Q = A \times B \times C \times F$$

Example: Find hourly capacity of a 2-in. line, 1000 ft long, with a pressure drop of 0.5-in. w.c.

Solution: $114 \times 2.24 \times 1.41 \times 13.6 = 4897$ cu ft per hr

---

To Find Pipe Diameter Required

CASE 2-A. All gas fed from one end of line and discharged at the other.

$$A = \frac{Q}{B \times C}$$

Example: Find pipe diameter required to deliver 3000 cu ft of gas per hour for a distance of 500 ft, with a pressure drop of 1.0-in. w.c.

Solution: $\frac{3000}{3.16 \times 2.00} = \frac{3000}{6.32}$ $A = 475$

From Table of "A" Factors, a 3-in. pipe would be required.

CASE 2-B. All gas fed from one end of line and discharged at intervals along the line.

$$A = \frac{Q}{B \times C \times D}$$

Example: Find the pipe diameter required to deliver 4000 cu ft of gas per hour, for a distance of 1000 ft, with a pressure drop of 0.6-in. w.c.

Solution: $\frac{4000}{2.45 \times 1.41 \times 1.7} = \frac{4000}{5.87}$ $A = 681.4$

From Table of "A" Factors, a 4-in. pipe would be required.

CASE 2-C. Gas fed from both ends of line and discharged at intervals along the line.

$$A = \frac{Q}{B \times C \times E}$$

Example: Find the pipe diameter required to deliver 9000 cu ft of gas per hour, for a distance of 950 ft, with a pressure drop of 1.5-in. w.c.

Solution: $\frac{9000}{3.87 \times 1.45 \times 4.8} = \frac{9000}{26.9}$ $A = 334.5$

From Table of "A" Factors, a 3-in. line would be required.

CASE 2-D. Gas fed from both ends and the middle of line and discharged at intervals along the line.

$$A = \frac{Q}{B \times C \times F}$$

Example: Find the pipe diameter required to deliver 5000 cu ft of gas per hour, for a distance of 725 ft, with a pressure drop of 0.4-in. w.c.

Solution: $\frac{5000}{2.00 \times 1.66 \times 13.6} = \frac{5000}{45.15}$ $A = 110.7$

From Table of "A" Factors, a 2-in. line would be required.

To Find Pressure Drop

CASE 3-A. All gas fed from one end of the line and discharged at the other end.

$$B = \frac{Q}{A \times C}$$

Example: Find the pressure drop in 600 ft of 4-in. pipe, where the rate of flow is 10,000 cu ft per hour.

Solution: $\frac{10{,}000}{715 \times 1.82} = \frac{10{,}000}{1301.3}$ $B = 7.68$

From Table of "B" Factors, pressure drop would be 5.9-in. w.c.

CASE 3-B. All gas fed from one end of line and discharged at intervals along the line.

$$B = \frac{Q}{A \times C \times D}$$

Example: Find the pressure drop in 500 ft of 4-in. pipe, where the rate of flow is 4000 cu ft per hour.

Solution: $\frac{4000}{715 \times 2.00 \times 1.7} = \frac{4000}{2431}$ $B = 1.645$

From Table of "B" Factors, pressure drop would be 0.3-in. w.c.

CASE 3-C. Gas fed from both ends of line and discharged at intervals along the line.

$$B = \frac{Q}{A \times C \times E}$$

Example: Find the pressure drop (difference in pressure between inlets and point of lowest pressure) in 800 ft of 3-in. pipe where the rate of flow is 10,000 cu ft per hour.

Solution: $\frac{10{,}000}{341 \times 1.58 \times 4.8} = \frac{10{,}000}{2586.1}$ $B = 3.867$

From Table of "B" Factors, pressure drop would be 1.5-in. w.c.

CASE 3-D. Gas fed from both ends and the middle of line and discharged at intervals along the line.

$$B = \frac{Q}{A \times C \times F}$$

Example: Find the pressure drop (difference in pressure between inlets and points of lowest pressure) in 1100 ft of 3-in. pipe, where the rate of flow is 15,000 cu ft per hour.

Solution: $\frac{15{,}000}{341 \times 1.35 \times 13.6} = \frac{15{,}000}{6260.76}$ $B = 2.395$

From Table of "B" Factors, pressure drop would be 0.6-in. w.c.

Factors To Use Distribution Flow Line Calculations

Table of "A" Factors

Standard Steel pipe data except when starred (*) to indicate cast iron pipe

Nominal Size Pipe (Inches)	Internal Diameter (Inches)	"A"	Nominal Size Pipe (Inches)	Internal Diameter (Inches)	"A"	Nominal Size Pipe (Inches)	Internal Diameter (Inches)	"A"
1	1.049	16.6	*6	6.200	2,240	16	15.500	22,600
1¼	1.380	36.5	8	8.071	4,430	*16	16.160	25,000
1½	1.610	56.5	*8	8.150	4,550	18	17.250	29,300
*2	1.875	86.9	10	10.020	7,680	18	17.375	29,800
2	2.067	114	*10	10.120	7,870	18	17.500	30,300
2½	2.469	187	10	10.136	7,900	20	19.250	38,100
*3	3.020	327	10	10.192	8,020	20	19.375	38,700
3	3.068	341	12	11.500	10,800	20	19.500	39,300
3½	3.548	505	12	12.090	12,300	*20	20.240	42,900
*4	4.000	701	*12	12.120	12,400			
4	4.026	715	12	12.188	12,500			
4½	4.506	965	14	13.250	15,400			
5	5.047	1,300	15	14.250	18,400			
*6	6.040	2,090	16	15.250	21,700			
6	6.065	2,120	16	15.375	22,200			

Table of "B" Factors

Pressure Drop (In. of Water)	"B"	Pressure Drop (In. of Water)	"B"	Pressure Drop (In. of Water)	"B"	Pressure Drop (In. of Water)	"B"	Pressure Drop (In. of Water)	"B"
.1	1.00	3.1	5.57	6.2	7.87	12.2	11.0	18.2	13.5
.2	1.41	3.2	5.66	6.4	8.00	12.4	11.1	18.4	13.6
.3	1.73	3.3	5.74	6.6	8.12	12.6	11.2	18.6	13.6
.4	2.00	3.4	5.83	6.8	8.25	12.8	11.3	18.8	13.7
.5	2.24	3.5	5.92	7.0	8.37	13.0	11.4	19.0	13.8
.6	2.45	3.6	6.00	7.2	8.48	13.2	11.5	19.2	13.9
.7	2.65	3.7	6.08	7.4	8.60	13.4	11.6	19.4	13.9
.8	2.83	3.8	6.16	7.6	8.72	13.6	11.7	19.6	14.0
.9	3.00	3.9	6.24	7.8	8.83	13.8	11.7	19.8	14.1
1.0	3.16	4.0	6.32	8.0	8.94	14.0	11.8	20.0	14.1
1.1	3.32	4.1	6.40	8.2	9.06	14.2	11.9		
1.2	3.46	4.2	6.48	8.4	9.16	14.4	12.0		
1.3	3.61	4.3	6.56	8.6	9.27	14.6	12.1		
1.4	3.74	4.4	6.63	8.8	9.38	14.8	12.2		
1.5	3.87	4.5	6.71	9.0	9.49	15.0	12.2		
1.6	4.00	4.6	6.78	9.2	9.59	15.2	12.3		
1.7	4.12	4.7	6.86	9.4	9.70	15.4	12.4		
1.8	4.24	4.8	6.93	9.6	9.80	15.6	12.5		
1.9	4.36	4.9	7.00	9.8	9.90	15.8	12.6		
2.0	4.47	5.0	7.07	10.0	10.0	16.0	12.6		
2.1	4.58	5.1	7.14	10.2	10.1	16.2	12.7		
2.2	4.69	5.2	7.21	10.4	10.2	16.4	12.8		
2.3	4.80	5.3	7.28	10.6	10.3	16.6	12.9		
2.4	4.90	5.4	7.35	10.8	10.4	16.8	13.0		
2.5	5.00	5.5	7.42	11.0	10.5	17.0	13.0		
2.6	5.10	5.6	7.48	11.2	10.6	17.2	13.1		
2.7	5.20	5.7	7.55	11.4	10.7	17.4	13.2		
2.8	5.29	5.8	7.62	11.6	10.8	17.6	13.3		
2.9	5.38	5.9	7.68	11.8	10.9	17.8	13.3		
3.0	5.48	6.0	7.75	12.0	11.0	18.0	13.4		

Table of "C" Factors

Length of Pipe (ft)	"C"	Length of Pipe (ft)	"C"	Length of Pipe (ft)	"C"	Length of Pipe (ft)	"C"	Length of Pipe (ft)	"C"
5	20.0	260	2.77	750	1.63	1,550	1.14	3,100	.803
10	14.1	280	2.67	775	1.61	1,600	1.12	3,200	.790
15	11.6	300	2.58	800	1.58	1,650	1.10	3,300	.778
20	10.0	325	2.48	825	1.56	1,700	1.08	3,400	.767
25	8.94	350	2.39	850	1.53	1,750	1.07	3,500	.756
30	8.17	375	2.31	875	1.51	1,800	1.05	3,600	.745
40	7.07	400	2.24	900	1.49	1,850	1.04	3,700	.735
50	6.32	425	2.17	925	1.47	1,900	1.03	3,800	.725
60	5.77	450	2.11	950	1.45	1,950	1.01	3,900	.716
70	5.35	475	2.05	1,000	1.41	2,000	1.00	4,000	.707
80	5.00	500	2.00	1,050	1.38	2,100	.976	4,100	.698
90	4.71	525	1.95	1,100	1.35	2,200	.953	4,200	.690
100	4.47	550	1.91	1,150	1.32	2,300	.932	4,300	.682
120	4.08	575	1.87	1,200	1.29	2,400	.913	4,400	.674
140	3.78	600	1.82	1,250	1.26	2,500	.894	4,500	.667
160	3.54	625	1.79	1,300	1.24	2,600	.877	4,600	.659
180	3.33	650	1.75	1,350	1.22	2,700	.861	4,700	.652
200	3.16	675	1.72	1,400	1.20	2,800	.845	4,800	.646
220	3.01	700	1.69	1,450	1.17	2,900	.830	4,900	.639
240	2.89	725	1.66	1,500	1.15	3,000	.816	5,000	.632

"D" Factor = 1.7 **"E" Factor = 4.8** **"F" Factor = 13.6**

Low Pressure Gas Flow

The Spitzglass Formulas

For distribution system problems the Spitzglass formulas are most commonly used. These formulas are:

FOR PRESSURES NOT EXCEEDING ONE POUND GAGE:

$$Q = 3550\,K\left(\frac{h}{S\,L}\right)^{\frac{1}{2}}$$

Where:

Q = Flow per hour in cu ft at 14.73 psia and 60F.
H = Pressure drop in inches of water column.
S = Specific gravity of gas. (Air = 1.0).
L = Length of pipe in feet.
d = Internal diameter of pipe in inches.

$$K = \left(\frac{d^5}{1 + \frac{3.6}{d} + 0.03d}\right)^{\frac{1}{2}}$$

FOR PRESSURES EXCEEDING ONE POUND GAGE:

$$Q = 4830\,K\left(\frac{Pa}{SL}\right)^{\frac{1}{2}}$$

Where:

Q = Flow per hour in cu ft at 14.73 psia and 60F.
P = Pressure drop between pipe terminals in psi.
a = Average pressure in pipe line, psia. (Absolute initial pressure minus half the pressure drop.)
S = Specific gravity of gas. (Air = 1.0).
L = Length of pipe in feet.
d = Internal Diameter of pipe in inches.

$$K = \left(\frac{d^5}{1 + \frac{3.6}{d} + 0.03d}\right)^{\frac{1}{2}}$$

Values of $\sqrt{d^5}$

Diameter (d) inches (internal)	$\sqrt{d^5}$
.75	.4871
.824 (¾" pipe)	.6163
1.000	1.000
1.049 (1" pipe)	1.127
1.38 (1¼" pipe)	2.237
1.50	2.756
1.61 (1½" pipe)	3.289
2.00	5.657
2.067 (2" pipe)	6.143
2.479 (2½" pipe)	9.579
3.00	15.59
3.068	16.49
4.00	32.00
4.026	32.52
6.00	88.18
8.00	181.0
10.00	316.2
12.00	498.8
16.00	1024.
20.00	1789.
24.00	2822.
30.00	4930.
36.00	7776.

The Fritzsche Formula

This variable density formula is recommended by some companies for computing systems having operating pressures of 15 psig or less, and more specifically, for the 2 to 15 psig range in small diameter pipe (8-in. or smaller). The formula is:

$$Q = \frac{1.72}{S^{0.462}}\,\frac{T_o}{P_o}\left[\frac{(P_1^2 - P_2^2)\,d^5}{10^3\,T_1\,L}\right]^{0.538}$$

and

$$Z = P_1^2 - P_2^2 = \frac{S^{0.86}}{2.72}\left(\frac{P_o}{T_o}\right)^{1.85}\left(\frac{T_1\,10^3\,L}{d^5}\right)Q^{1.85}$$

($Z = (P_1^2 - P_2^2)$ or $(fP_1 - fP_2)$ in studies of compressible gases)

$$Z = \left(\frac{2.614\,S^{0.86}}{10^4}\right)\left(\frac{10^6\,L}{d^5}\right)Q^{1.85}$$

Where:

Q = flow in cubic feet per hour at 14.73 psi and 60F
$T_o = T_1 = 520$ R
$P_o = 14.73$ psi
S = 0.65 sp gr

The Pole Formula

Another formula that has been used in computing low pressure services is the Pole formula, expressed as follows:

$$Q = 876\sqrt{\frac{d^5\,h}{g\,l}}$$

Where:

Q = Flow per hour in cubic feet at 60F
d = inside diameter, inches
h = pressure drop
g = specific gravity of gas (air = 1.0)
l = length of main in ft

Values of $d^{8/3}$

Diameter in Inches External	Internal (d)	$d^{8/3}$
2.375	2.067	6.93
2.500	3.068	19.87
4.500	4.026	41.02
6.625	6.065	122.4
8.625	7.981	254.3
10.75	10.02	466.8
12.75	12.00	755.0
14.00	13.25	983.5
16.00	15.25	1,430.2
18.00	17.25	1,986.6
20.00	19.25	2,661.6
22.00	21.25	3,465.0
24.00	23.125	4,340.8
26.00	25.125	5,415.0
28.00	27.125	6,642.3
30.00	29.125	8,030.0

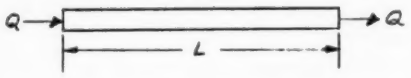
FACTORS TO APPLY TO LOW PRESSURE FORMULAS (1-LB AND UNDER) UNDER VARYING CONDITIONS TO OBTAIN GAS DELIVERY QUANTITIES

When the main is fed from one end and discharged at the other:

Assuming that the pressure drop h and the specific gravity S remain constant, then the only variable in the Spitzglass formula

$$Q = 3550\ K \sqrt{\frac{h}{SL}}$$

Example A



is the length L

$$\therefore\ 3550\ K \sqrt{\frac{h}{s}} = \text{constant} = C$$

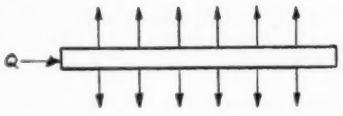
$$\text{then } Q = C \sqrt{\frac{1}{L}}$$

total flow when main is fed from one end and discharged at the other.

When the main is fed from one end and discharged at intervals along the main line:

This factor was obtained from the Gas Engineers' Handbook.* Assuming equal intervals between services, equal demands per service, and a total of 40 services on the line. This factor is correct within 1.0 per cent from 20 to 10,000 services on the line.

Example B



$$\text{then } Q = 1.7\ C \sqrt{\frac{1}{L}}$$

total flow when main is fed from one end and discharged at intervals along the line.

(*Published by McGraw-Hill Book Company, New York, New York, 1934.)

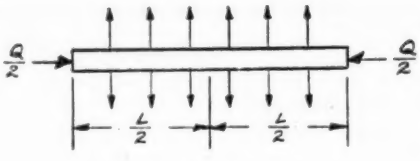
When the main is fed from both ends and discharged at intervals along the line:

Assume that ½ of the total flow is being fed through each end, then the point of no flow would be at ½ of the total length.

From EXAMPLE B,

Example C

$$\frac{Q}{2} = 1.7\ C \sqrt{\frac{\frac{1}{L}}{2}} = 1.7\ C \sqrt{\frac{2}{L}}$$



$$Q = 2 \times 1.7 \sqrt{2}\ C \sqrt{\frac{1}{L}}$$

$$Q = 4.8\ C \sqrt{\frac{1}{L}}$$

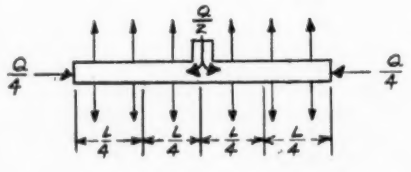
total flow when main is fed from both ends and discharged at intervals along the line.

When the main is fed from both ends and the middle and discharged along the line:

Assume that the flow fed at the middle is double that fed at each end, the point of no flow would be ¼ the total length from EXAMPLE B,

Example D

$$\frac{Q}{4} = 1.7\ C \sqrt{\frac{\frac{1}{L}}{4}} = 1.7\ C \sqrt{\frac{4}{L}}$$



$$Q = 4 \times 2 \times 1.7\ C \sqrt{\frac{1}{L}}$$

$$Q = 13.6\ C \sqrt{\frac{1}{L}}$$

total flow when main is fed from both ends and the middle and discharged at intervals along the line.

Gas Flow Formulas

THE WEYMOUTH FORMULA

Most widely used formula in the gas industry for calculating the flow of natural gas through pipelines is the Weymouth Formula, developed by Thomas R. Weymouth, and expressed as:

$$Q = 433.45 \frac{T_o}{P_o} \left(\frac{d^{16/3}}{GTL}\right)^{1/2} (P_1^2 - P_2^2)^{1/2} . \quad . \quad (1)$$

Where:

Q = flow per 24 hr day at standard conditions P_o and T_o

d = internal diameter of pipe in inches

L = length of line in miles

G = specific gravity of gas (Air = 1.0)

T_o = absolute temperature base of measurement (460 + F)

T = absolute temperature of flowing gas (460 + F)

P_o = absolute pressure base of measurement (psia)

P_1 = initial pressure (psia)

P_2 = terminal pressure (psia)

The original formula given above agrees closely with metered rates of flow, but at higher pressures, error increases due to the deviation of gases from ideal gas laws. To compensate for this, a compressibility factor must be introduced. This factor is: $(1 + JP_m)^{1/2}$

Where:

$$P_m = \tfrac{2}{3} \left(P_1 + P_2 - \frac{P_1 P_2}{P_1 + P_2}\right)$$

and J= factor determined by the relationship:

$$(1 + JP) = \frac{1}{Z}$$

Weymouth's formula, modified for supercompressibility, then becomes:

$$Q = 433.45 \frac{T_o}{P_o} \left(\frac{d^{16/3}}{GTL}\right)^{1/2} (P_1^2 - P_2^2)^{1/2} (1 + JP_m)^{1/2}$$

This may also be expressed as:

$$Q = 433.45 \frac{T_o}{P_o} \left(\frac{d^{16/3}}{GTL}\right)^{1/2} \times [P_1^2 (1 + \tfrac{2}{3} JP_1) - P_2^2 (1 + \tfrac{2}{3} JP_2)]^{1/2}$$

Many individuals and companies have developed various methods and shortcuts for simplifying calculations of gas flow using the Weymouth formula. While types of natural gas vary across the country, most gas companies can resolve the natural gas in their system into one composite.

This allows the development of a single constant "K" based on known standards of pressure, temperature, flowing temperature, and physical characteristics of the gas being transported, and constant values for the pressure variables based on a specific supercompressibility factor (Z).

Considering only the pressure variables in the formula and further modifying it for compressibility, we have:

$$\left(\frac{Q}{C}\right)^2 = (P_1^2 - P_2^2) \ (1 + JP_m)$$

where $C = 433.45 \frac{T_o}{P_o} \left(\frac{d^{16/3}}{GTL}\right)^{1/2}$

$$\left(\frac{Q}{C}\right)^2 = (P_1^2 - P_2^2) \left[1 + \tfrac{2}{3} J \left(P_1 + P_2 - \frac{P_1 P_2}{P_1 + P_2}\right)\right]$$

$$= (P_1^2 + \tfrac{2}{3} JP_1^3) - (P_2^2 + \tfrac{2}{3} JP_2^3)$$

For purposes of simplification, let:

$$(P^2 + \tfrac{2}{3} JP^3) = P^2 (1 + \tfrac{2}{3} JP) = fP$$

Then:

$$\left(\frac{Q}{C}\right)^2 = fP_1 - fP_2$$

and,

$$Q = C (fP_1 - fP_2)^{1/2}$$

The values of fP are given in Table 1, where P (for either P_1 or P_2) is given as the pressure in psig and the values of fP are based on absolute pressures (P + 14.73), using J = 0.00018 as an average for pipeline natural gases.

Further simplification is possible by establishing K as a constant, using $P_o = 14.73$ psia; $T_o = 520$ (460 + 60); T = 520 (460 + 60), and S = 0.60.

$$K = 433.45 \frac{T_o}{P_o} \left(\frac{1}{GT}\right)^{1/2}$$

$$= 433.45 \frac{520}{14.73} \left(\frac{1}{0.6 \times 520}\right)^{1/2}$$

$$= 866.67$$

(If flow is to be computed for cu ft per hour, K = 36.111)

The formula is then reduced to:

$$Q = 866.67 \left(\frac{d^{16/3}}{L}\right)^{1/2} \times (fP_1 - fP_2)^{1/2}$$

$$= 866.67 \frac{d^{8/3}}{L^{1/2}} (fP_1 - fP_2)^{1/2} \quad . \quad . \quad . \quad . \quad (2)$$

Values of $d^{8/3}$ or $d^{16/3}$, $\frac{1}{L^{1/2}}$, and fP are given in Tables 1, 2, and 6.

For those desiring to establish a different value for the constant K, Tables 3, 4, and 5 can be used as follows:

$$K_o = 433.45 \times T_o \times \frac{1}{P_o} \times \frac{1}{G^{1/2}} \times \frac{1}{T^{1/2}} . \quad . \quad (3)$$

An even simpler version of the formula, suitable for office use and preliminary design calculations can be established for the basic formula (without modification for supercompressibility) as follows:

$$Q = 866.67 \times \frac{d^{8/3}}{L^{1/2}} (P_1^2 - P_2^2)^{1/2} . \quad . \quad . \quad (4)$$

Values of P_1^2 and P_2^2 can be obtained from Table 7, which gives P in psig and the squares in absolute pressures (P + 14.73).

Methods of Calculation

Based on the preceding derivations, using $K_D = 866.67$ for volume in 24 hr and $K_H = 36.111$ for volume in 1 hr, and using values from the tables the following calculations can be made:

To find rate of flow (Q):

$$Q_{\text{per day}} = 866.67 \times d^{8/3} \times \frac{1}{L^{1/2}} \times (fP_1 - fP_2)^{1/2} \quad . \quad (2)$$

$$Q_{\text{per hour}} = 36.111 \times d^{8/3} \times \frac{1}{L^{1/2}} \times (fP_1 - fP_2)^{1/2} \quad . \quad (5)$$

To find pipe diameter (d):

$$d^{8/3} = \frac{Q \times L^{1/2}}{866.67 \times (fP_1 - fP_2)^{1/2}} \quad . \quad . \quad . \quad (6)$$

After value of $d^{8/3}$ is determined, value of d can be read from Table 2, either directly or by extrapolation using two pipe sizes whose $d^{8/3}$ values are nearest the calculated figures.

To find length of line (L):

$$L^{1/2} = \frac{866.67}{Q} \times d^{8/3} (fP_1 - fP_2)^{1/2} \quad . \quad . \quad . \quad (7)$$

After value of $L^{1/2}$ is determined, value of L can be calculated simply by squaring the value of $L^{1/2}$.

To find initial pressure (P_1):

$$(fP_1 - fP_2)^{1/2} = \frac{Q \times L^{1/2}}{K \times d^{8/3}} = (fP_d)^{1/2} \quad . \quad . \quad (8)$$

$$fP_1 - fP_2 = fP_d$$

$$fP_1 = fP_d + fP_2$$

Since P_2 is a known value, the value of fP_2 can be found in Table 1. To this is added the value of fP_d, determined by the calculation; the total equals fP_1, which can be checked against values in Table 1 to determine the value of P_1.

To find terminal pressure (P_2):

Procedure is similar to above, calculating for value of $(fP_d)^{1/2}$.

Then:

$$fP_2 = fP_1 - fP_d \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Since P_1 is a known value, the value of fP_1 can be found in Table 1; from this value, subtract fP_d; this gives the value of fP_2, which can be checked against values in Table 1 to determine value of P_2.

Examples

Example 1

Find total flow in std cu ft of gas per day through a 20-in. O.D., .375-in. wall pipe 100 miles long. Inlet pressure is 600 psia, and outlet pressure is 100 psia.

Procedure:

Use formula (2)

From Table 6, $d^{8/3}$ for 20-in. O.D., 375-in. wall is 2662

From Table 2, $1/L^{1/2}$ for 100 miles is 0.10

From Table 1, fP_1 (for 600 psia) is 404,850

From Table 1, fP_2 (for 100 psia) is 13,264

Then:

$$Q = 866.67 \times 2662 \times 0.10 \times (404{,}850 - 13{,}264)^{1/2}$$

$$= 234{,}000 \times (391{,}586)^{1/2}$$

$$= 142{,}974{,}000 \text{ std cu ft per day}$$

Example 2

Find pipe size to deliver 150,000,000 std cu ft of gas per day through a line 100 miles long. Inlet pressure is 600 psia; outlet pressure is 100 psia.

Procedure:

Use formula (6)

From Table 1, fP_1 (for 600 psia) is 404,850

From Table 1, fP_2 (for 100 psia) is 13,264

Then:

$$d^{8/3} = \frac{150{,}000{,}000 \times (100)^{1/2}}{866.67 \times (404{,}850 - 13{,}264)^{1/2}}$$

$$= \frac{1{,}500{,}000{,}000}{529{,}533}$$

$$= 3460$$

From Table 2, select pipe sizes having a value for $d^{8/3}$ above 3460. Several pipe sizes meet this criteria:

22-in. O.D., .375-in. wall — $d^{8/3} = 3464$

22-in. O.D., .344-in. wall — $d^{8/3} = 3491$

22-in. O.D., .312-in. wall — $d^{8/3} = 3519$

Obviously, 22-in. O.D. pipe will be used. Selection of the proper wall thickness should be made according to the ASA Code B 31.8 — 1958 (*See Working Pressures of Pipe* tables on following pages of Handbook.) From those tables, it is found that 22-in. O.D., .344-in. wall, API 5LX-42 pipe meets code requirements for all Type A, B, and C construction. For Class D construction, 22-in. O.D., .375-in. wall, API 5LX-46 pipe should be used.

Calculations for Complex Pipeline Systems

Rarely does a pipeline system have but one size of pipe throughout its entire length. Most systems consist of sections of pipe of various diameters or have lines that are paralleled (looped) with other lines. As daily demand increases, common practice is to parallel sections of the system with pipe of the same or different diameter. Extensions of existing systems are often constructed of pipe of different diameter than the original. The results of these practices — to meet constantly changing conditions — are complex pipeline systems. The following formulas and calculation examples are commonly used with the Weymouth Formula.

The general principle involved is to convert the various diameters and lengths of pipeline in a complex system to equivalent lengths of a common diameter or to equivalent diameters of a common length. From these determinations, the dimensions of a single line with a delivery capacity equivalent to the complex system are obtained.

In all cases, in the following formulas and examples, it is assumed that pressures, temperature, and specific gravity are constant, and that the only variables affecting volume of gas flowing are length and diameter of the pipeline. Therefore:

$$L_1 = L_2 \left(\frac{d_1}{d_2}\right)^{16/3} \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

Where L_1 = the equivalent length of any pipe of length L_2 and diameter d_2 in terms of diameter d_1.

$$d_1 = d_2 \left(\frac{L_1}{L_2}\right)^{3/16} \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

Where d_1 = the equivalent diameter of any pipe of a given diameter d_2 and the length L_2 in terms of any other length L_1.

In a complex system, consisting of parallel lines of the same length, the equivalent diameter can be used in calculating the flow of gas as follows:

$$Q = 866.67 \times \frac{1}{L^{1/2}} \times (fP_1 - fP_2)^{1/2} \times (d_1^{8/3} + d_2^{8/3} \cdots + d_n^{8/3}) \quad . \quad . \quad (12)$$

where d_1, d_2, $\cdots$ d_n are the diameters of the individual lines.

The equivalent diameter, d_o, of a single line that has the same delivery capacity as that of the parallel lines is:

$$d_o^{8/3} = (d_1^{8/3} + d_2^{8/3} \cdots + d_n^{8/3})$$

or

$$d_o = (d_1^{8/3} + d_2^{8/3} \cdots + d_n^{8/3})^{3/8} \quad . \quad . \quad (13)$$

The calculated value of the equivalent diameter, d_o, can be substituted directly into the formula for computing flow.

Example 3 (Series System)

Determine rate of flow in std cu ft per hour of a pipeline consisting of 20 miles of 14-in. OD, .375-in. wall; 20 miles of 16-in. OD, .375-in. wall, and 30 miles of 18-in. OD, .375-in. wall, connected in series. Inlet pressure is 600 psia and outlet pressure is 100 psia.

Procedure:

Having both variable lengths and diameters, the easiest and most practical solution is to determine the equivalent length of each section of the system adjusted to a common diameter. The system is then equivalent to a continuous line of one diameter with a length equal to the sum of the equivalent lengths of the various sections.

By using the 20-mile middle section, with an internal diameter of 15.250-in., as the common diameter, the other two sections can be converted to equivalent lengths of the common diameter by using values of $d^{16/3}$ from Table 6 as follows:

The 20-mile, 14-in. OD section (13.250-in. ID) is equivalent to:

$$L_1 = 20 \left(\frac{15.250}{13.250}\right)^{16/3} = 20 \left(\frac{2{,}040{,}000}{966{,}000}\right)$$

$$= 42.238 \text{ miles of } 15.250\text{-in. ID pipe}$$

The 30-mile, 18-in. OD section (17.250-in. ID) is equivalent to:

$$L_1 = 30 \left(\frac{15.250}{17.250}\right)^{16/3} = 30 \left(\frac{2{,}040{,}000}{3{,}950{,}000}\right)$$

$$= 15.492 \text{ miles of } 15.250\text{-in. ID pipe}$$

The entire system is equivalent to the sum of these lengths, $42.238 + 15.492 + 20 = 77.73$ miles of 15.250-in. ID pipe. The quantity of gas flowing may then be determined as shown in Example 1.

Example 4 (Looped System)

Determine rate of flow in std cu ft per hour of a pipeline consisting of 100 miles of 16-in. OD, .375-in. wall (15.250-in. ID) pipe, looped for a distance of 30 miles with 14-in. OD, .375-in. wall, (13.250-in. ID) pipe. Pressures, temperatures, and specific gravity are same as in Example 1.

Procedure:

First, convert the 30-mile looped section into a single line 30 miles long with a diameter equivalent to the two parallel lines of 15.250-in. ID and 13.250-in. ID, as follows:

$d_o = (15.250^{8/3} + 13.250^{8/3})^{3/8}$ (See Table 6 for $d^{8/3}$ values)

$d_o = (1430 + 983)^{3/8} = 18.555$-in., equivalent diameter of a single line 30 miles long.

The system is now equivalent to two sections in series, one 30 miles long of 18.555-in. ID pipe and one 70 miles long of 15.250-in. ID pipe. Either section can be converted to an equivalent length of the other section of the same diameter. Convert the 30-mile section of 18.555-in. ID pipe to an equivalent length of 15.250-in. ID pipe, as follows:

$$L_1 = 30 \left(\frac{15.250}{18.555}\right)^{16/3} = 30 \left(\frac{2{,}040{,}000}{5{,}823{,}000}\right)$$

$$= 10.50 \text{ miles of } 15.250\text{-in. ID pipe, equivalent to } 30 \text{ miles of } 18.555\text{-in. ID pipe.}$$

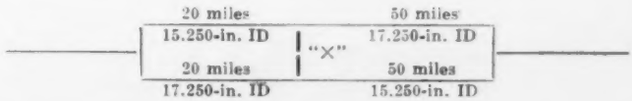
The complete system in terms of a single line of one diameter is $70 + 10.5 = 80.5$ miles of 15.250-in. ID pipe. The quantity of gas flowing may then be determined as shown in Example 1.

When a looped section consists of several lines of unequal length, the equivalent diameter for one of the lines is determined for a length equal to the other line, then converted into an equivalent single line of one diameter.

Example 5 (Special Complex System)

This example illustrates not only the use of the formulas to calculate flow in complex systems, but also points out the importance of connections at certain points on looped systems.

System being considered consists of two parallel lines (A and B) connected at the inlet and outlet. Line A consists of 20 miles of 16-in. OD (15.250-in. ID) followed by 50 miles of 18-in. OD (17.250-in. ID). Line B consists of 20 miles of 18-in. OD (17.250-in. ID) followed by 50 miles of 16-in. OD (15.250-in. ID) as shown below:



For line A, the equivalent length in 15.250-in. ID pipe is:

$$L_1 = 20\left(\frac{15.250}{17.250}\right)^{16/3} = 50\left(\frac{2{,}040{,}000}{3{,}950{,}000}\right)$$

= 25.82 miles of 15.250-in. ID equivalent to 50 miles of 17.250-in. ID pipe.

Line A is then equivalent to 20 + 25.82 = 45.82 miles of 15.250-in. ID pipe.

For line B, the equivalent length in 15.250-in. ID pipe is:

$$\left(\frac{15.250}{17.250}\right) \quad L_1 = 50^{\,16/3} = 20\left(\frac{2{,}040{,}000}{3{,}950{,}000}\right)$$

= 10.328 miles of 15.250-in. ID equivalent to 20 miles of 17.250-in. ID pipe.

Line B is then equivalent to 50 + 10.328 = 60.328 miles of 15.250-in. ID pipe.

The entire system is now the equivalent of two looped lines of the same diameter (15.250-in. ID), one of 45.82 miles and one of 60.328 miles. Next step is to determine equivalent diameter of one of the lines when made equivalent in length to the other; the 45.82 miles of 15.250-in. ID pipe is the same as 60.328 miles with an equivalent diameter of:

$$d_1 = 15.250\left(\frac{60.328}{45.82}\right)^{3/16} = 16.06\text{-in. ID}$$

The equivalent system now consists of two looped lines each 60.328 miles long, one of 16.06-in. ID and one of 15.250-in. ID. The equivalent of this system is further reduced to one line, 60.328 miles long, with a common diameter:

$$d_0 = (16.06^{8/3} + 15.250^{8/3})^{3/8} = 20.313\text{-in. ID}$$

The system now equals a single line, 60.328 miles long, with a diameter of 20.313-in.

If a connection were made at point **"X"** in the diagram, the system would then be equivalent to two looped lines, both 70 miles long, one with a diameter of 15.250-in. and one with a diameter of 17.250-in. The equivalent diameter of these two looped lines would then be:

$$d_0 = (15.250^{8/3} + 17.250^{8/3})^{3/8} = 21.141\text{-in. ID}$$

With the connection at "**X**," the system becomes equivalent to a single line of 70 miles length having a diameter of 21.141-in. ID. For purposes of comparison to the same system without the connection, this 70 miles of 21.141-in. ID pipe is equivalent to 60.328 miles of

$$d_1 = 21.141\left(\frac{60.328}{70}\right)^{3/16} = 20.837\text{-in. ID pipe.}$$

Thus it can be seen that the advantage in connecting the system at point **"X"** is the increased delivery capacity of a line 60.328 miles long of 20.837-in. ID compared to the same length of line (without connection) with an internal diameter of 20.313-in. ID., assuming that all other factors influencing the flow are the same in both lines.

PARALLEL PIPELINE SYSTEMS

Where a pipeline system has but a single line, small increases in demand can usually be met by increasing operating pressures. Any great increase, however, requires "looping" or paralleling sections of the existing system.

In the following, the lines are defined as "original line" and "parallel line." The parallel line may or may not extend the entire length of the original line. Both ends of the parallel line, however, are connected to the original line.

The formulas given below are derived from the Weymouth Formula and were developed to aid in designing parallel systems.

The formulas are applicable under the conditions that whenever a section of the original line is paralleled, the temperature and specific gravity of the gas and pressures at the inlet and outlet ends of the original line are the same as they were before paralleling.

In all the formulas given below, the following definitions apply:

X = portion of the original line length that is to be paralleled; *this is expressed decimally.*

d = internal diameter of original line in inches

d_1 = internal diameter of parallel line in inches

Q = rate of flow through system before paralleling at specified conditions of pressure and temperature

Q_1 = rate of flow through the system after paralleling, at specified conditions of pressure and temperature

The first formula is used to determine what portion of the entire length of the line must be paralleled with the same or different diameter pipe to increase the volume of flow to the desired amount:

$$X = \frac{\left(\frac{Q}{Q_1}\right)^2 - 1}{\left(\frac{1}{\left[1 - \left(\frac{d_1}{d}\right)^{8/3}\right]^2}\right) - 1} \quad \ldots\ldots (14)$$

This formula can also be arranged to determine the volume flowing through a system for any value of X (percent of original line length parallel) for any diameter pipe:

$$Q_1 = \frac{Q}{\left[X\left(\frac{1}{\left[1 + \left(\frac{d_1}{d}\right)^{8/3}\right]^2} - 1\right) + 1\right]^{1/2}} \quad \ldots (15)$$

The formula can also be arranged to determine the diameter required for the parallel line to provide a given amount of gas flow for a given portion (X) of the original line paralleled.

$$\frac{d_1}{d} = \left(\left[\frac{X}{\left(\frac{Q}{Q_1}\right)^2 - 1 + X}\right]^{1/2} - 1\right)^{3/8} \quad \ldots (16)$$

When the value of X is 1 (whenever the entire length of the original line has been paralleled), the following relationship may be used:

$$\frac{Q_1}{Q} = 1 + \left(\frac{d_1}{d}\right)^{8/3} \quad . \quad . \quad . \quad . \quad . \quad (17)$$

When the diameters of the original and parallel lines are the same, the formulas simplify to:

$$X = \frac{4}{3}\left[1 - \left(\frac{Q}{Q_1}\right)^2\right] \quad . \quad . \quad . \quad (18)$$

and

$$\frac{Q_1}{Q} = \frac{2}{(4 - 3X)^{1/2}} \quad . \quad . \quad . \quad . \quad . \quad (19)$$

Example 6

Given: A pipeline, 100 miles long, 22-in. OD pipe, .375-in. wall (21.250 ID) delivering 150,000,000 std cu ft of gas per day. It is desired to increase delivery by 33 percent (to 200,000,000 std cu ft per day) by paralleling with 20-in. OD pipe (19.250-in. ID), while maintaining the same inlet and outlet pressures. Find length of original line that must be paralleled:

$$X = \frac{\left(\frac{150{,}000{,}000}{200{,}000{,}000}\right)^2 - 1}{\left(\frac{1}{\left[1 + \left(\frac{19.250}{21.250}\right)^{8/3}\right]^2}\right) - 1}$$

$$= \frac{-.43750}{.32 - 1} = .643$$

Since X = .643, the delivery capacity can be increased from 150,000,000 to 200,000,000 cu ft by paralleling 64.3 percent of the original line (64.3 mile) using 20-in. OD pipe of .375-in. wall (19.250-in. ID).

Example 7

Given: A 50-mile, 16-in. OD pipeline (15.250-in. ID) delivering 100,000,000 cu ft of gas per day. If 20 miles of the original length is paralleled with 18-in. OD pipe (17.250-in. ID) find delivery of system after paralleling.

$$Q_1 = \frac{100{,}000{,}000}{\left[0.4\left(\frac{1}{\left[1 + \left(\frac{17.250}{15.250}\right)^{8/3}\right]^2 - 1}\right) + 1\right]^{1/2}}$$

$$= \frac{100{,}000{,}000}{(-.3302 + 1)^{1/2}} = \frac{100{,}000{,}000}{.8184}$$

$$= 122{,}200{,}000 \text{ cu ft of gas per day}$$

Delivery would then be increased by 22.2 percent.

Example 8

Given: A pipeline 60 miles long, 18-in. OD, (17.250-in. ID) delivering 90,000,000 cu ft of gas per day. If delivery is to be increased 50 percent (to 135,000,000 cu ft per day) by paralleling 45 miles (75 percent) of the original line length, and maintaining the same inlet and outlet pressures, what diameter pipe would be required for the parallel line?

$$\frac{d_1}{d} = \left(\left[\frac{0.75}{\left(\frac{90{,}000{,}000}{135{,}000{,}000}\right)^2 - 1.0 + 0.75}\right]^{1/2} - 1\right)^{3/8}$$

$$= (1.962 - 1)^{3/8} = .9816$$

From this, $d_1 = 17.250 \times .9816 = 16.92$-in. ID, the pipe size that would be required. In actual design, 18-in. OD pipe would be used with wall thickness to withstand line pressure with a reasonable safety factor.

STORAGE CAPACITY OF PIPELINES

The volume of gas that can be stored in a line is obtained by use of the equation:

$$V = 1.955\, d^2\, L\, P_m\, K \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (20)$$

Where:

d = inside diameter of line in inches

L = length of line in miles

P_m = mean line pressure, psi

$K = \left(\frac{1}{Z}\right)^{1/2}$ supercompressibility factor for a gas of given specific gravity at given temperature (obtain Z from Tables in this handbook).

The value of P_m can be found from the equation:

$$P_m = \frac{2}{3}\left[P_1 + P_2 - \frac{P_1 P_2}{P_1 + P_2}\right] \quad . \quad . \quad (21)$$

Where:

P_1 = inlet pressure, psia

P_2 = outlet pressure, psia

Through the use of Equation 20, the total quantity of gas in a line at a constant rate of flow (when input just equals discharge) can be quickly calculated.

To calculate the quantity of gas that can be stored (or withdrawn from storage) between the period of low flow and the period of high flow, it is necessary only to find V_1 (volume during low flow) by using the low flow pressures in the P_m calculation and to find V_2 (volume during high flow) by using the high flow pressures in the P_m calculation. The difference between the two is the storage capacity of the line.

TABLE 1. Values of fP in thousands

Pressure psi-Gage (P_1 or P_2)	0	1	2	3	4	5	6	7	8	9
0	.20771	.23759	.26948	.30338	.33930	.37722	.41716	.45912	.50309	.54907
10	.59707	.64709	.69913	.75319	.80926	.86736	.92748	.98961	1.0538	1.1200
20	1.1882	1.2584	1.3306	1.4049	1.4812	1.5596	1.6399	1.7223	1.8068	1.8932
30	1.9817	2.0722	2.1648	2.2593	2.3559	2.4546	2.5553	2.6580	2.7627	2.8695
40	2.9784	3.0892	3.2021	3.3171	3.4341	3.5531	3.6742	3.7973	3.9224	4.0496
50	4.1789	4.3102	4.4435	4.5789	4.7163	4.8558	4.9973	5.1409	5.2865	5.4342
60	5.5840	5.7357	5.8896	6.0455	6.2034	6.3634	6.5255	6.6896	6.8558	7.0240
70	7.1943	7.3666	7.5410	7.7175	7.8961	8.0767	8.2593	8.4441	8.6308	8.8197
80	9.0106	9.2031	9.3987	9.5958	9.7950	9.9962	10.200	10.405	10.612	10.822
90	11.034	11.247	11.463	11.681	11.901	12.123	12.347	12.573	12.801	13.032
100	13.264	13.498	13.735	13.974	14.214	14.457	14.702	14.949	15.198	15.449
110	15.702	15.958	16.215	16.475	16.736	17.000	17.266	17.534	17.804	18.076
120	18.350	18.626	18.904	19.185	19.467	19.752	20.039	20.328	20.618	20.912
130	21.207	21.504	21.803	22.105	22.408	22.714	23.022	23.331	23.643	23.958
140	24.274	24.592	24.912	25.235	25.560	25.886	26.215	26.546	26.879	27.214
150	27.552	27.891	28.233	28.576	28.922	29.270	29.620	29.972	30.326	30.683
160	31.041	31.402	31.765	32.130	32.496	32.866	33.237	33.610	33.986	34.363
170	34.743	35.125	35.509	35.895	36.286	36.674	37.067	37.461	37.858	38.257
180	38.658	39.062	39.467	39.874	40.274	40.696	41.110	41.526	41.944	42.364
190	42.787	43.212	43.638	44.067	44.498	44.932	45.367	45.805	46.244	46.686
200	47.130	47.576	48.025	48.475	48.928	49.382	49.839	50.298	50.760	51.223
210	51.689	52.156	52.626	53.098	53.572	54.049	54.527	55.008	55.491	55.976
220	56.463	56.952	57.444	57.938	58.433	58.931	59.432	59.934	60.438	60.945
230	61.454	61.965	62.478	62.994	63.511	64.031	64.553	65.077	65.603	66.132
240	66.662	67.195	67.730	68.267	68.806	69.348	69.892	70.438	70.986	71.536
250	72.088	72.643	73.200	73.759	74.320	74.884	75.449	76.017	76.587	77.159
260	77.733	78.310	78.889	79.470	80.053	80.638	81.226	81.815	82.407	83.001
270	83.598	84.196	84.797	85.400	86.005	86.612	87.221	87.834	88.448	89.064
280	89.682	90.303	90.926	91.550	92.178	92.807	93.439	94.073	94.709	95.347
290	95.988	96.630	97.275	97.922	98.572	99.223	99.877	100.53	101.19	101.85
300	102.51	103.18	103.85	104.52	105.19	105.86	106.54	107.22	107.90	108.58
310	109.26	109.95	110.64	111.33	112.02	112.72	113.42	114.12	114.82	115.53
320	116.24	116.94	117.66	118.37	119.09	119.80	120.53	121.25	121.97	122.70
330	123.43	124.16	124.90	125.63	126.37	127.11	127.86	128.60	129.35	130.10
340	130.85	131.61	132.36	133.12	133.88	134.65	135.41	136.18	136.95	137.72
350	138.50	139.27	140.05	140.83	141.62	142.40	143.19	143.98	144.78	145.57
360	146.37	147.17	147.97	148.77	149.58	150.39	151.20	152.01	152.83	153.64
370	154.46	155.29	156.11	156.94	157.77	158.60	159.43	160.27	161.11	161.95
380	162.79	163.64	164.48	165.33	166.18	167.04	167.89	168.75	169.61	170.48
390	171.34	172.21	173.08	173.95	174.83	175.70	176.58	177.47	178.35	179.24
400	180.12	181.01	181.91	182.80	183.70	184.60	185.50	186.41	187.31	188.22
410	189.14	190.05	190.96	191.88	192.80	193.73	194.65	195.58	196.51	197.44
420	198.17	199.31	200.25	201.19	202.14	203.08	204.03	204.98	205.93	206.89
430	207.85	208.81	209.77	210.73	211.70	212.67	213.64	214.62	215.59	216.57
440	217.55	218.53	219.52	220.51	221.50	222.49	223.48	224.48	225.48	226.48
450	227.48	228.49	229.50	230.51	231.52	232.54	233.56	234.58	235.60	236.63
460	237.65	238.68	239.72	240.75	241.79	242.82	243.87	244.91	245.96	247.00
470	248.06	249.11	250.16	251.22	252.28	253.34	254.41	255.48	256.54	257.62
480	258.69	259.77	260.85	261.93	263.01	264.10	265.18	266.28	267.37	268.46
490	269.56	270.66	271.76	272.87	273.95	275.09	276.20	277.31	278.43	279.55
500	280.67	281.79	282.92	284.05	285.18	286.31	287.45	288.58	289.72	290.87
510	292.01	293.16	294.31	295.46	296.62	297.76	298.93	300.09	301.26	302.42
520	303.59	304.76	305.94	307.11	308.29	309.47	310.65	311.84	313.03	314.22
530	315.41	316.60	317.80	319.00	320.20	321.41	322.62	323.82	325.04	326.25
540	327.47	328.68	329.91	331.13	332.36	333.58	334.82	336.05	337.28	338.52
550	339.76	341.00	342.25	343.50	344.75	346.00	347.25	348.51	349.80	351.03
560	352.30	353.56	354.83	356.10	357.38	358.66	359.94	361.22	362.50	363.79
570	365.07	366.36	367.66	368.95	370.25	371.55	372.86	374.16	375.47	376.78
580	378.09	379.41	380.72	382.04	383.37	384.69	386.02	387.35	388.68	390.01
590	391.35	392.69	394.03	395.38	396.72	398.07	399.42	400.78	402.13	403.49
600	404.85	406.22	407.58	408.95	410.32	411.70	413.07	414.45	415.83	417.21
610	418.60	419.99	421.38	422.77	424.17	425.56	426.96	428.37	429.77	431.18
620	432.59	434.00	435.42	436.84	438.26	439.68	441.10	442.53	443.96	445.39
630	446.83	448.26	449.70	451.14	452.59	454.04	455.48	456.94	458.39	459.85
640	461.31	462.77	464.23	465.70	467.17	468.64	470.11	471.59	473.07	474.55
650	476.03	477.52	479.01	480.50	481.99	483.49	484.99	486.49	487.99	489.50
660	491.01	492.52	494.03	495.55	497.07	498.59	500.11	501.64	503.17	504.70
670	506.23	507.77	509.30	510.85	512.39	513.94	515.48	517.03	518.59	520.14
680	521.70	523.26	524.82	526.39	527.96	529.53	531.10	532.68	534.26	535.84
690	537.42	539.01	540.60	542.18	543.78	545.37	546.97	548.57	550.18	551.78
700	553.39	555.00	556.61	558.23	559.85	561.47	563.09	564.72	566.35	567.98
710	569.61	571.25	572.88	574.53	576.17	577.82	579.46	581.11	582.77	584.42
720	586.08	587.74	589.41	591.07	592.74	594.41	596.09	597.76	599.44	601.12
730	602.80	604.49	606.18	607.87	609.56	611.26	612.96	614.66	616.37	618.07
740	619.78	621.49	623.21	624.92	626.64	628.36	630.09	631.82	633.54	635.28
750	637.01	638.75	640.49	642.23	643.97	645.72	647.47	649.22	650.98	652.74
760	654.49	656.26	658.02	659.79	661.56	663.33	665.11	666.88	668.66	670.45
770	672.23	674.02	675.81	677.60	679.40	681.20	683.00	684.80	686.61	688.42
780	690.23	692.04	693.86	695.68	697.50	699.32	701.15	702.98	704.81	706.64
790	708.48	710.32	712.16	714.00	715.85	717.70	719.55	721.40	723.26	725.12
800	726.98	728.85	730.72	732.59	734.46	736.34	738.21	740.09	741.98	743.86
810	745.75	747.64	749.53	751.43	753.33	755.23	757.13	759.04	760.95	762.86
820	764.77	766.69	768.61	770.53	772.45	774.38	776.31	778.24	780.18	782.12
830	784.06	786.00	787.94	789.89	791.84	793.79	795.75	797.71	799.67	801.63
840	803.60	805.56	807.54	809.51	811.49	813.46	815.45	817.43	819.42	821.41
850	823.40	825.39	827.39	829.39	831.39	833.40	835.41	837.42	839.43	841.44
860	843.46	845.48	847.51	849.54	851.56	853.59	855.63	857.66	859.70	861.74
870	863.79	865.84	867.88	869.93	871.99	874.05	876.11	878.17	880.24	882.31
880	884.38	886.45	888.53	890.60	892.69	894.77	896.86	898.95	901.04	903.13
890	905.23	907.33	909.43	911.54	913.64	915.75	917.87	919.98	922.10	924.22
900	926.34	928.47	930.60	932.73	934.86	937.00	939.14	941.28	943.43	945.58
910	947.72	949.88	952.03	954.19	956.35	958.51	960.68	962.85	965.02	967.19
920	969.37	971.55	973.73	975.92	978.10	980.29	982.49	984.68	986.88	989.08
930	991.28	993.49	995.70	997.91	1000.1	1002.3	1004.6	1006.8	1009.0	1011.2
940	1013.5	1015.7	1017.9	1020.2	1022.4	1024.6	1026.9	1029.1	1031.4	1033.6
950	1035.9	1038.2	1040.4	1042.7	1045.0	1047.2	1049.5	1051.8	1054.0	1056.3
960	1058.6	1060.9	1063.2	1065.5	1067.8	1070.1	1072.4	1074.7	1077.0	1079.3
970	1081.6	1083.9	1086.2	1088.6	1090.9	1093.2	1095.5	1097.8	1100.2	1102.5
980	1104.9	1107.2	1109.5	1111.9	1114.2	1116.6	1118.9	1121.3	1123.6	1126.0
990	1128.4	1130.8	1133.1	1135.5	1137.9	1140.2	1142.6	1145.0	1147.4	1149.8

TABLE 1. (continued) Values of fP in thousands

Pressure psi-Gage (P_1 or P_2)	0	1	2	3	4	5	6	7	8	9
1000	1152.2	1154.6	1157.0	1159.4	1161.8	1164.2	1166.6	1169.0	1171.4	1173.8
1010	1176.2	1178.7	1181.1	1183.5	1185.9	1188.4	1190.8	1193.2	1195.7	1198.1
1020	1200.6	1203.0	1205.5	1207.9	1210.4	1212.8	1215.3	1217.8	1220.2	1222.7
1030	1225.2	1227.7	1230.2	1232.6	1235.1	1237.6	1240.1	1242.6	1245.1	1247.6
1040	1250.1	1252.6	1255.1	1257.6	1260.1	1262.6	1265.1	1267.7	1270.2	1272.7
1050	1275.2	1277.8	1280.3	1282.8	1285.4	1287.9	1290.5	1293.0	1295.6	1298.1
1060	1300.7	1303.2	1305.8	1308.4	1310.9	1313.5	1316.1	1318.6	1321.2	1323.8
1070	1326.4	1329.0	1331.6	1334.2	1336.8	1339.4	1342.0	1344.6	1347.2	1349.8
1080	1352.4	1355.0	1357.6	1360.2	1362.8	1365.5	1368.1	1370.7	1373.4	1376.0
1090	1378.6	1381.3	1383.9	1386.6	1389.2	1391.9	1394.5	1397.2	1399.9	1402.5
1100	1405.2	1407.8	1410.5	1413.2	1415.9	1418.6	1421.2	1423.9	1426.6	1429.3
1110	1432.0	1434.7	1437.4	1440.1	1442.8	1445.5	1448.2	1451.0	1453.7	1456.4
1120	1459.1	1461.8	1464.6	1467.3	1470.0	1472.8	1475.5	1478.3	1481.0	1483.8
1130	1486.5	1489.2	1492.0	1494.8	1497.5	1500.3	1503.1	1505.8	1508.6	1511.4
1140	1514.2	1517.0	1519.7	1522.5	1525.3	1528.1	1530.9	1533.7	1536.5	1539.3
1150	1542.1	1544.9	1547.7	1550.6	1553.4	1556.2	1559.0	1561.8	1564.7	1567.5
1160	1570.3	1573.2	1576.0	1578.9	1581.7	1584.6	1587.4	1590.3	1593.1	1596.0
1170	1598.8	1601.7	1604.6	1607.5	1610.3	1613.2	1616.1	1619.0	1621.9	1624.8
1180	1627.6	1630.5	1633.4	1636.3	1639.2	1642.2	1645.1	1648.0	1650.9	1653.8
1190	1656.7	1659.6	1662.6	1665.5	1668.4	1671.4	1674.3	1677.3	1680.2	1683.2
1200	1686.1	1689.1	1692.0	1695.0	1697.9	1700.9	1703.8	1706.8	1709.8	1712.8
1210	1715.8	1718.7	1721.7	1724.7	1727.7	1730.7	1733.7	1736.7	1739.7	1742.7
1220	1745.7	1748.7	1751.7	1754.7	1757.7	1760.8	1763.8	1766.8	1769.8	1772.9
1230	1775.9	1779.0	1782.0	1785.0	1788.1	1791.1	1794.2	1797.2	1800.3	1803.4
1240	1806.4	1809.5	1812.6	1815.6	1818.7	1821.8	1824.9	1828.0	1831.0	1834.1
1250	1837.2	1840.3	1843.4	1846.5	1849.6	1852.7	1855.8	1859.0	1862.1	1865.2
1260	1868.3	1871.4	1874.6	1877.7	1880.8	1884.0	1887.1	1890.3	1893.4	1896.6
1270	1899.7	1902.8	1906.0	1909.2	1912.3	1915.5	1918.7	1921.8	1925.0	1928.2
1280	1931.4	1934.6	1937.8	1940.9	1944.1	1947.3	1950.5	1953.7	1956.9	1960.1
1290	1963.3	1966.6	1969.8	1973.0	1976.2	1979.4	1982.7	1985.9	1989.1	1992.4
1300	1995.6	1998.8	2002.1	2005.3	2008.6	2011.8	2015.1	2018.4	2021.6	2024.9
1310	2028.1	2031.4	2034.7	2038.0	2041.2	2044.5	2047.8	2051.1	2054.4	2057.7
1320	2061.0	2064.3	2067.6	2070.9	2074.2	2077.5	2080.8	2084.2	2087.5	2090.8
1330	2094.1	2097.5	2100.8	2104.1	2107.5	2110.8	2114.2	2117.5	2120.9	2124.2
1340	2127.5	2130.9	2134.3	2137.6	2141.0	2144.4	2147.8	2151.2	2154.5	2157.9
1350	2161.3	2164.7	2168.1	2171.5	2174.9	2178.3	2181.7	2185.1	2188.5	2191.9
1360	2195.3	2198.7	2202.2	2205.6	2209.0	2212.4	2215.9	2219.3	2222.8	2226.2
1370	2229.6	2233.1	2236.6	2240.0	2243.5	2246.9	2250.4	2253.8	2257.3	2260.8
1380	2264.3	2267.8	2271.2	2274.7	2278.2	2281.7	2285.2	2288.7	2292.2	2295.7
1390	2299.2	2302.7	2306.2	2309.7	2313.2	2316.8	2320.3	2323.8	2327.3	2330.9
1400	2334.4	2338.0	2341.5	2345.0	2348.6	2352.1	2355.7	2359.2	2362.8	2366.4
1410	2369.9	2373.5	2377.1	2380.6	2384.2	2387.8	2391.4	2395.0	2398.6	2402.2
1420	2405.8	2409.4	2413.0	2416.6	2420.2	2423.8	2427.4	2431.0	2434.6	2438.2
1430	2441.9	2445.5	2449.1	2452.8	2456.4	2460.0	2463.7	2467.3	2471.0	2474.6
1440	2478.3	2482.0	2485.6	2489.3	2493.0	2496.6	2500.3	2504.0	2507.6	2511.3
1450	2515.0	2518.7	2522.4	2526.1	2529.8	2533.5	2537.2	2540.9	2544.6	2548.3
1460	2552.1	2555.8	2559.5	2563.2	2567.0	2570.7	2574.4	2578.2	2581.9	2585.6
1470	2589.4	2593.1	2596.9	2600.6	2604.4	2608.2	2611.9	2615.7	2619.5	2623.2
1480	2627.0	2630.8	2634.6	2638.4	2642.2	2646.0	2649.8	2653.6	2657.4	2661.2
1490	2665.0	2668.8	2672.6	2676.4	2680.2	2684.1	2687.9	2691.7	2695.6	2699.4

TABLE 2. Values of $\frac{1}{L^{½}}$

Miles	0	1	2	3	4	5	6	7	8	9
		1.0000	0.7071	0.5773	0.5000	0.4472	0.4082	0.3780	0.3536	0.3333
10	0.3162	.3015	.2887	.2773	.2673	.2582	.2500	.2425	.2357	.2294
20	.2236	.2182	.2132	.2085	.2041	.2000	.1961	.1924	.1890	.1857
30	.1826	.1796	.1768	.1741	.1715	.1690	.1667	.1644	.1622	.1601
40	.1581	.1562	.1543	.1525	.1508	.1491	.1474	.1459	.1443	.1429
50	.1414	.1400	.1387	.1374	.1361	.1348	.1336	.1325	.1313	.1302
60	.1291	.1280	.1270	.1260	.1250	.1240	.1231	.1222	.1213	.1204
70	.1195	.1187	.1179	.1170	.1162	.1155	.1147	.1140	.1132	.1125
80	.1118	.1111	.1104	.1098	.1091	.1085	.1078	.1072	.1066	.1060
90	.1054	.1048	.1043	.1037	.1031	.1026	.1021	.1015	.1010	.1005

Miles	0	10	20	30	40	50	60	70	80	90
100	0.1000	0.0953	0.0913	0.0877	0.0845	0.0816	0.0791	0.0767	0.0745	0.0725
200	.0707	.0690	.0674	.0659	.0645	.0632	.0620	.0609	.0598	.0587
300	.0577	.0568	.0559	.0550	.0542	.0535	.0527	.0520	.0513	.0506
400	.0500	.0494	.0488	.0482	.0477	.0471	.0466	.0461	.0456	.0452
500	.0447	—	—	—	—	—	—	—	—	—

TABLE 3. Values of $\frac{1}{G^{½}}$

G	$1/G^{½}$	G	$1/G^{½}$	G	$1/G^{½}$
0.600	1.2910	0.607	1.2835	0.614	1.2762
0.601	1.2899	0.608	1.2825	0.615	1.2752
0.602	1.2888	0.609	1.2814	0.616	1.2741
0.603	1.2878	0.610	1.2804	0.617	1.2731
0.604	1.2867	0.611	1.2793	0.618	1.2721
0.605	1.2857	0.612	1.2782	0.619	1.2710
0.606	1.2846	0.613	1.2772	0.620	1.2700

TABLE 4. Values of $\frac{1}{P_o}$

P_o	$1/P_o$	P_o	$1/P_o$	P_o	$1/P_o$
14.525	0.068847	15.400	0.064935	16.525	0.060514
14.650	0.068259	15.525	0.064412	16.650	0.060060
14.730	0.067889	15.650	0.063898	16.775	0.059612
14.775	0.067682	15.775	0.063391	16.900	0.059172
14.900	0.067114	15.900	0.062893	17.025	0.058737
15.025	0.066556	16.025	0.062403	17.150	0.058309
15.150	0.066007	16.275	0.061444	17.275	0.057887
15.275	0.065466	16.400	0.060976	17.400	0.057471

TABLE 5. Values of $\frac{1}{T^{½}}$ for various values of T (where T = 460 + t)

t	$1/T^{½}$	t	$1/T^{½}$	t	$1/T^{½}$	t	$1/T^{½}$
40	0.044721	50	0.044281	60	0.043853	70	0.043437
41	0.044676	51	0.044237	61	0.043811	71	0.043396
42	0.044632	52	0.044194	62	0.043769	72	0.043356
43	0.044588	53	0.044151	63	0.043727	73	0.043315
44	0.044544	54	0.044108	64	0.043685	74	0.043274
45	0.044499	55	0.044065	65	0.043644	75	0.043234
46	0.044455	56	0.044023	66	0.043602	76	0.043193
47	0.044412	57	0.043980	67	0.043561	77	0.043153
48	0.044368	58	0.043938	68	0.043519	78	0.043113
49	0.044324	59	0.043895	69	0.043478	79	0.043073
						80	0.043033

TABLE 6. Values of $d^{\frac{1}{2}}$ and other data for API pipe

Diameters		Weight per foot plain ends	Wall thickness			
Outside D Ins.	Inside d Ins.	Lbs.	t Ins.	d^5	$d^{8/3}$	$d^{16/3}$
3.500	3.250	4.51	.125	$.363\times10^3$	$.232\times10^3$	$.537\times10^5$
3.500	3.188	5.58	.156	.329	.220	.485
3.500	3.124	6.63	.188	.298	.209	.435
3.500	3.068	7.58	.216	.272	.199	.395
3.500	3.000	8.68	.250	.243	.187	.350
3.500	2.938	9.67	.281	.219	.177	.314
4.000	3.750	5.17	.125	.742	.339	1.152
4.000	3.688	6.41	.156	.682	.325	1.054
4.000	3.624	7.63	.188	.625	.310	.960
4.000	3.500	10.01	.250	.525	.282	.797
4.000	3.438	11.17	.281	.480	.269	.725
4.500	4.250	5.84	.125	1.387	.474	2.246
4.500	4.188	7.25	.156	1.288	.456	2.077
4.500	4.124	8.64	.188	1.193	.437	1.913
4.500	4.062	10.00	.219	1.106	.420	1.764
4.500	4.026	10.79	.237	1.058	.410	1.683
4.500	4.000	11.35	.250	1.024	.403	1.626
4.500	3.938	12.67	.281	.947	.387	1.496
4.500	3.876	13.98	.312	.875	.371	1.374
5.563	5.251	9.02	.156	3.992	.833	6.939
5.563	5.187	10.76	.188	3.755	.806	6.500
5.563	5.125	12.49	.219	3.536	.781	6.096
5.563	5.047	14.62	.258	3.275	.749	5.617
5.563	5.001	15.87	.281	3.128	.731	5.349
5.563	4.939	17.52	.312	2.939	.707	5.005
5.563	4.875	19.16	.344	2.753	.683	4.669
6.625	6.249	12.89	.188	9.529	1.325	1.755×10^4
6.625	6.187	14.97	.219	9.066	1.290	1.664
6.625	6.125	17.02	.250	8.620	1.256	1.577
6.625	6.065	18.97	.280	8.206	1.223	1.497
6.625	6.001	21.07	.312	7.782	1.189	1.414
6.625	5.937	23.06	.344	7.376	1.156	1.336
6.625	5.875	25.03	.375	6.999	1.124	1.263
8.625	8.249	16.90	.188	$.382\times10^5$	$.278\times10^3$	$.772\times10^5$
8.625	8.187	19.64	.219	.368	.272	.741
8.625	8.125	22.36	.250	.354	.267	.712
8.625	8.071	24.70	.277	.342	.262	.687
8.625	8.001	27.74	.312	.328	.256	.656
8.625	7.981	28.55	.322	.324	.254	.647
8.625	7.937	30.40	.344	.315	.251	.628
8.625	7.875	33.04	.375	.303	.245	.603
8.625	7.749	38.26	.438	.279	.235	.553
10.750	10.374	21.15	.188	1.202×10^5	$.512\times10^3$	2.620×10^5
10.750	10.312	24.60	.219	1.166	.504	2.538
10.750	10.250	28.04	.250	1.131	.496	2.458
10.750	10.192	31.20	.279	1.100	.488	2.384
10.750	10.136	34.24	.307	1.070	.481	2.315
10.750	10.062	38.20	.344	1.031	.472	2.227
10.750	10.020	40.48	.365	1.010	.467	2.178
10.750	9.874	48.19	.438	.939	.449	2.014
12.750	12.312	29.28	.219	2.829	.808	6.533
12.750	12.250	33.38	.250	2.759	.797	6.359
12.750	12.188	37.45	.281	2.689	.787	6.189
12.750	12.126	41.51	.312	2.622	.776	6.023
12.750	12.090	43.77	.330	2.583	.770	5.928
12.750	12.062	45.55	.344	2.553	.765	5.856
12.750	12.000	49.56	.375	2.488	.755	5.697
12.750	11.874	57.53	.438	2.360	.734	5.385
14.000	13.500	36.71	.250	4.484	1.030	1.068×10^5
14.000	13.438	41.21	.281	4.382	1.021	1.042
14.000	13.376	45.68	.312	4.282	1.008	1.016
14.000	13.312	50.14	.344	4.181	.995	.991
14.000	13.250	54.57	.375	4.084	.983	.966
14.000	13.124	63.37	.438	3.893	.958	.918
14.000	13.000	72.09	.500	3.713	.934	.873
16.000	15.500	42.05	.250	$.895\times10^5$	1.494	$.223\times10^7$
16.000	15.438	47.22	.281	.877	1.478	.218
16.000	15.376	52.36	.312	.859	1.462	.214
16.000	15.312	57.48	.344	.842	1.446	.209
16.000	15.250	62.58	.375	.825	1.430	.204
16.000	15.124	72.72	.438	.791	1.399	.196
16.000	15.000	82.77	.500	.759	1.368	.187
18.000	17.500	47.39	.250	1.641	2.064	.426
18.000	17.438	53.22	.281	1.612	2.045	.418
18.000	17.376	59.03	.312	1.584	2.026	.410
18.000	17.312	64.82	.344	1.555	2.006	.402
18.000	17.250	70.59	.375	1.527	1.987	.395
18.000	17.124	82.06	.438	1.473	1.948	.380
18.000	17.000	93.45	.500	1.420	1.911	.365
20.000	19.500	52.73	.250	2.820	2.755	.759
20.000	19.438	59.23	.281	2.775	2.732	.746
20.000	19.376	65.71	.312	2.731	2.708	.734
20.000	19.312	72.16	.344	2.686	2.684	.721
20.000	19.250	78.60	.375	2.643	2.662	.708
20.000	19.124	91.41	.438	2.558	2.615	.684
20.000	19.000	104.13	.500	2.476	2.570	.661
22.000	21.376	72.38	.312	4.463×10^5	3.519×10^3	1.239×10^7
22.000	21.312	79.51	.344	4.397	3.491	1.219
22.000	21.250	86.61	.375	4.333	3.464	1.200
22.000	21.124	100.75	.438	4.206	3.410	1.163
22.000	21.000	114.81	.500	4.084	3.357	1.127
24.000	23.376	79.06	.312	6.980	4.467	1.996
24.000	23.312	86.85	.344	6.885	4.435	1.967
24.000	23.250	94.62	.375	6.794	4.403	1.939
24.000	23.124	110.10	.438	6.612	4.340	1.884
24.000	23.000	125.49	.500	6.436	4.278	1.830
26.000	25.376	85.73	.312	10.522	5.560	3.092
26.000	25.250	102.63	.375	10.264	5.487	3.011
26.000	25.124	119.44	.438	10.010	5.415	2.932
26.000	25.000	136.17	.500	9.766	5.344	2.856
28.000	27.376	92.41	.312	1.538×10^7	$.681\times10^4$	$.463\times10^5$
28.000	27.250	110.64	.375	1.503	.672	.452
28.000	27.124	128.79	.438	1.468	.664	.441
28.000	27.000	146.85	.500	1.435	.656	.430
28.000	26.874	164.83	.563	1.402	.648	.420
30.000	29.376	99.08	.312	2.188	.822	.675
30.000	29.250	118.65	.375	2.141	.812	.660
30.000	29.124	138.13	.438	2.095	.803	.645
30.000	29.000	157.53	.500	2.051	.794	.630
30.000	28.874	176.85	.563	2.007	.786	.616
32.000	31.376	105.76	.312	3.041	.979	.959
32.000	31.250	126.66	.375	2.980	.969	.939
32.000	31.124	147.48	.438	2.921	.958	.919
32.000	31.000	168.21	.500	2.863	.948	.899
32.000	30.874	188.86	.563	2.805	.938	.880
34.000	33.376	112.43	.312	4.142	1.155	1.334
34.000	33.250	134.67	.375	4.064	1.143	1.307
34.000	33.124	156.82	.438	3.988	1.132	1.281
34.000	33.000	178.89	.500	3.914	1.120	1.255
34.000	32.874	200.88	.563	3.839	1.109	1.230
36.000	35.376	119.11	.312	5.540	1.349	1.819
36.000	35.250	142.68	.375	5.442	1.336	1.784
36.000	35.124	166.17	.438	5.346	1.323	1.751
36.000	35.000	189.57	.500	5.252	1.311	1.718
36.000	34.874	212.89	.563	5.158	1.298	1.685

TABLE 7. Values of P (in psig) and P_a^2 (where P_a = psig + 14.73)

P	0	1	2	3	4	5	6	7	8	9
0	217	247	280	314	351	389	430	472	517	563
10	612	662	714	769	825	884	944	1007	1071	1138
20	1206	1277	1349	1424	1500	1578	1659	1741	1826	1912
30	2001	2091	2184	2278	2375	2473	2574	2676	2780	2887
40	2995	3106	3218	3333	3449	3568	3688	3811	3935	4062
50	4190	4320	4453	4587	4724	4862	5003	5145	5290	5436
60	5585	5735	5887	6042	6198	6357	6517	6680	6844	7011
70	7179	7350	7522	7697	7873	8051	8232	8414	8599	8785
80	8974	9164	9357	9551	9748	9946	10,147	10,349	10,553	10,760
90	10,968	11,179	11,391	11,606	11,822	12,041	12,261	12,484	12,708	12,935

P	0	10	20	30	40	50	60	70	80	90
100	13,163	15,558	18,152	20,947	23,941	27,136	30,531	34,125	37,920	41,914
200	46,109	50,504	55,098	59,893	64,887	70,135	75,477	81,071	86,866	92,860
300	99,055	105,450	112,044	118,839	125,833	133,028	140,423	148,017	155,812	163,806
400	172,001	180,396	188,990	197,785	206,779	215,974	225,369	234,963	244,758	254,752
500	264,947	275,342	285,936	296,731	307,725	318,920	330,315	341,909	353,704	365,698
600	377,893	390,288	402,882	415,677	428,671	441,866	455,261	468,855	482,650	496,644
700	510,839	525,234	539,828	554,623	569,617	584,812	600,207	615,801	631,596	647,590
800	663,785	680,180	696,774	713,569	730,563	747,758	765,153	782,747	800,542	818,536
900	836,731	855,126	873,720	892,515	911,509	930,704	950,099	969,693	989,488	1,009,482
1000	1,029,677									

For a line with a static pressure condition, P, uniform throughout the length of the line, the following equations can be used: To determine storage capacity of the line (atmospheric pressure = 14.73 psia):

Cu ft per 100 ft $= 0.03703\ P\ d^2\ K$

Cu ft per ft $= 0.0003703\ P\ d^2\ K$

Cu ft per 1000 ft $= 0.3703\ P\ d^2\ K$

Cu ft per mile $= 1.955\ P\ d^2\ K$

Example 9

Given: A pipeline 200 miles long, 20-in. OD pipe (19.250-in. ID) is operated under conditions given below. Determine the quantity of gas that can be stored in the line. Gas temperature is 60 F and specific gravity is 65.

Period of low flow $P_1 = 800,\ P_2 = 600\ (P_m = 705)$

Period of high flow $P_1 = 800,\ P_2 = 400\ (P_m = 622)$

From the supercompressibility charts, the Z factors are found for the two P_m values and the values of K are calculated from $K = \left(\frac{1}{Z}\right)^{1/2}$.

Then:

$V_1 = 1.955\ d^2\ L\ P_m\ K$

$= 725 \times 200 \times 705 \times 1.087$

$= 111{,}000{,}000$ std cu ft

and

$V_2 = 725 \times 200 \times 622 \times 1.075$
$= 96{,}000{,}000$ std cu ft

Storage capacity of the line is then equal to $V_1 - V_2 =$ 15,000,000 cu ft of gas at standard conditions.

The Panhandle Formula*

The original Panhandle Flow Formula has been used by numerous companies for calculating flow in large diameter (12-in. or larger, lines. This basic formula is:

$$Q = 435.87e \left(\frac{T_o}{P_o}\right)^{1.07881} \left(\frac{(P_1^2 - P_2^2)}{G^{0.8539} T_f L}\right)^{0.5394} d^{2.6182}$$

By substituting:

T_o = Base temperature = 60° +460° = 520° abs
P_o = Base pressure = 14.73 psia
T_f = Flowing temperature = 50° + 460° = 510° abs
G = Gravity of gas = 0.686 (Panhandle gas)

and where:

P_1 = Initial pressure — psia
P_2 = Final pressure — psia
L = Length of line in miles
d = Diameter of pipe in inches
e = Experience factor

the equation can be resolved to:

$$Q/d^{2.6182} = 839.51e \left(\frac{(P_1^2 - P_2^2)}{L}\right)^{0.5394}$$

Recently, this formula was revised, and the revision is known as the "Modified Panhandle Flow Formula." The complete formula accounts for differences in elevation and compressibility. For calculations requiring only a fair amount of accuracy, these two factors can be omitted. The simplified version of the modified formula is:

$$Q = 737 \left(\frac{T_o}{P_o}\right)^{1.02} E \left(\frac{P_1^2 - P_2^2}{T_f L\ G^{.961}}\right)^{0.510} \times D^{2.53}$$

Where:

Q = cubic feet per day at P_o and T_o,
T_o = base temperature, F abs,
P_o = base pressure, psia,

*Complete details on how the modified formula was derived were given in the May and June, 1956, issues of *Pipeline Engineer*, along with a graphical method of solution.

E = efficiency factor,

P_1 = upstream pressure, psia,

P_2 = downstream pressure, psia,

T_f = flowing temperature, F abs,

L = length of pipe line, miles,

G = gas gravity referred to air,

D = inside diameter of pipe, in.

The equation can be separated into its components as follows:

$$Q = 737 \times \left(\frac{T_0}{P_0}\right)^{1.02} \times \left(\frac{1}{T_f}\right)^{0.510} \times \left(\frac{1}{G}\right)^{.4901} \times \left(\frac{1}{L}\right)^{.510} \times D^{2.53} \times E \times P_1^{1.02} \left(\frac{r^2-1}{r^2}\right)^{.510}$$

Normally T_0, P_0, T_f, and G will remain constant for a design problem, therefore, these components can be grouped together in one table. The following tables can be prepared:

(a) F_{GT_f} = Temperature-gravity function ..... Table 1

$$F_{GT_f} = 737 \left(\frac{T_0}{P_0}\right)^{1.02} \times \left(\frac{1}{T_f}\right)^{.510} \times \left(\frac{1}{G}\right)^{.4901}$$

(b) F_p = Pressure function ..... Table II

$$F_p = (P_1)^{1.02}$$

(c) F_L = Pipe line length function ..... Table III

$$F_L = \left(\frac{1}{L}\right)^{.510}$$

(d) F_D = Pipe line diameter function ..... Table IV

$$F_D = D^{2.53}$$

(e) F_r = Ratio function ..... Table V

$$r = \frac{P_1}{P_2}$$

$$F_r = \left(\frac{r^2-1}{r^2}\right)^{.510}$$

The flow equation then simplifies to the very workable form of:

$$Q = F_{GT} \times F_p \times F_L \times F_D \times F_r \times E$$

Several examples will illustrate the use of the tables.

Example No. 1

Find the volume that can be carried in a pipe line 80 miles in length and with an inside diameter of 25.375 in. (26 in. OD).

Given:

P_0 = 14.73 psia
T_0 = 60 F or 520°R
T_f = 60 F or 520°R
G = 0.650
E = 92 per cent
P_1 = 900 psia
P_2 = 550 psia

Then:

$$r = \frac{P_1}{P_2} = \frac{900}{550} = 1.64$$

$$Q = F_{GT} \times F_p \times F_L \times F_D \times F_r \times E$$

F_{GT} = 1421.57 ..... Table I
F_p = 1031.2 ..... Table II
F_L = 0.10701 ..... Table III
F_D = 3574.8 ..... Table IV
F_r = 0.78892 ..... Table V

$Q = 1421.57 \times 1031.2 \times 0.10701 \times 3574.8 \times 0.78892 \times 0.92 =$ **407,000** MCF/Day.

Example No. 2

Find the downstream pressure, P_2

Given:

P_0 = 14.73
T_0 = 60 F
P_1 = 1000 psia
T_f = 80 F
G = 0.600
D = 35.250 in. ID (36 in. OD)
L = 100 miles
Q = 900 MMCF/Day
E = 95 per cent

$$F_r = \frac{Q}{F_{GT} \times F_p \times F_L \times F_D \times E}$$

F_{GT} = 1450.03 ..... Table I
F_p = 1148.2 ..... Table II
F_L = 0.09550 ..... Table III
F_D = 8209.4 ..... Table IV

$$F_r = \frac{900{,}000{,}000}{1450.03 \times 1148.2 \times 0.09550 \times 8209.4 \times .95}$$

F_r = 0.72579
r = 1.46 ..... Table V

$$P_2 = \frac{1000}{1.46} = \textbf{685} \text{ psia}$$

TABLE IV. Pipe diameter function — F_D

OD, in.	Wall thickness, in.	I.D., in.	F_D $(ID)^{2.53}$	OD, in.	Wall thickness, in.	I.D., in.	F_D $(ID)^{2.53}$
2⅜	0.154	2.067	6.2778	16	0.219	15.562	1037.4
3½	0.216	3.068	17.051		0.250	15.500	1026.9
	0.300	2.900	14.786		0.281	15.438	1016.6
4½	0.237	4.026	33.910		0.312	15.375	1006.1
	0.337	3.926	31.819		0.344	15.312	995.71
6⅝	0.250	6.125	98.032		0.375	15.250	985.53
	0.280	6.065	95.622		0.438	15.125	965.23
	0.432	5.761	83.956	18	0.250	17.500	1396.0
8⅝	0.187	8.250	208.27		0.281	17.438	1383.5
	0.203	8.219	206.30		0.312	17.375	1370.9
	0.219	8.187	204.27		0.344	17.312	1358.4
	0.250	8.125	200.38		0.375	17.250	1346.1
	0.277	8.071	197.02		0.409	17.182	1332.7
	0.322	7.981	191.51		0.438	17.125	1321.6
10¾	0.203	10.344	369.12	20	0.250	19.500	1835.6
	0.219	10.312	366.23		0.281	19.438	1820.9
	0.250	10.250	360.69		0.312	19.375	1806.0
	0.279	10.192	355.55		0.344	19.312	1791.2
	0.307	10.136	350.62		0.375	19.250	1776.6
	0.344	10.062	344.18		0.409	19.182	1760.8
	0.365	10.020	340.56		0.438	19.125	1747.6
12¾	0.203	12.344	577.28	22	0.250	21.500	2350.0
	0.219	12.312	573.50		0.281	21.438	2332.9
	0.250	12.250	566.22		0.312	21.375	2315.6
	0.281	12.188	559.00		0.344	21.312	2298.4
	0.312	12.125	551.72		0.375	21.250	2281.4
	0.330	12.090	547.68		0.438	21.125	2247.7
	0.344	12.062	544.49		0.500	21.000	2214.2
	0.375	12.000	537.43	24	0.250	23.500	2943.1
	0.438	11.875	523.39		0.281	23.438	2923.5
14	0.210	13.580	734.90		0.312	23.375	2903.6
	0.219	13.562	732.44		0.344	23.312	2883.9
	0.250	13.500	724.00		0.375	23.250	2864.5
	0.281	13.438	715.63		0.438	23.125	2825.7
	0.312	13.375	706.57		0.500	23.000	2787.2
	0.344	13.312	698.77				
	0.375	13.250	690.56				

TABLE I. F_{GT} = gravity-temperature function — $737.0 \left(\frac{T_o}{P_o}\right)^{1.02} \left(\frac{I}{G}\right)^{1.4901} \left(\frac{I}{T_r}\right)^{0.510}$

Temperature, F	Gravity 0.600	0.610	0.620	0.630	0.640	0.650	0.660	0.670	0.680	0.690	0.700
35	1515.9	1503.7	1491.8	1480.1	1468.7	1457.6	1446.7	1436.1	1425.7	1415.6	1405.6
40	1508.3	1496.1	1484.2	1472.6	1461.3	1450.3	1439.4	1428.9	1418.5	1408.4	1398.5
45	1500.5	1488.4	1476.6	1465.1	1453.8	1442.8	1432.1	1421.6	1411.3	1401.2	1391.4
50	1492.8	1480.8	1469.0	1457.6	1446.4	1435.4	1424.7	1414.2	1404.0	1394.0	1384.2
55	1485.4	1473.4	1461.7	1450.3	1439.2	1428.3	1417.6	1407.2	1397.0	1387.1	1377.3
60	1478.4	1466.4	1454.8	1443.4	1432.3	1421.5	1410.9	1400.5	1390.4	1380.5	1370.8
65	1470.9	1459.1	1447.5	1436.2	1425.1	1414.3	1403.8	1393.5	1383.4	1373.5	1363.9
70	1463.8	1452.0	1440.5	1429.2	1418.2	1407.5	1397.0	1386.7	1376.7	1366.9	1357.3
75	1457.1	1445.3	1433.8	1422.6	1411.7	1401.0	1390.6	1380.4	1370.4	1360.6	1351.0
80	1449.9	1438.2	1426.8	1415.6	1404.7	1394.1	1383.7	1373.5	1363.6	1353.9	1344.4
85	1443.1	1431.4	1420.1	1409.0	1398.2	1387.6	1377.2	1367.1	1357.2	1347.5	1338.1
90	1436.7	1425.1	1413.7	1402.7	1391.9	1381.4	1371.1	1361.0	1351.2	1341.5	1332.1
95	1429.8	1418.3	1407.0	1396.0	1385.3	1374.8	1364.5	1354.5	1344.7	1335.1	1325.7
100	1423.3	1411.8	1400.6	1389.7	1379.0	1368.5	1358.3	1348.4	1338.6	1329.1	1319.7
105	1416.8	1405.3	1394.2	1383.3	1372.7	1362.3	1352.1	1342.2	1332.5	1323.0	1313.7
110	1410.6	1399.2	1388.1	1377.3	1366.7	1356.4	1346.2	1336.4	1326.7	1317.2	1308.0
115	1404.5	1393.1	1382.1	1371.3	1360.7	1350.4	1340.4	1330.5	1320.9	1311.5	1302.3
120	1398.3	1387.0	1376.0	1365.2	1354.7	1344.5	1334.5	1324.7	1315.1	1305.7	1296.5
125	1392.0	1380.8	1369.8	1359.1	1348.7	1338.5	1328.5	1318.8	1309.2	1299.9	1290.7
130	1385.8	1374.6	1363.7	1353.0	1342.7	1332.5	1322.6	1312.8	1303.4	1294.1	1285.0
135	1379.9	1368.8	1357.9	1347.3	1337.0	1326.9	1317.0	1307.3	1297.8	1288.6	1279.5
140	1374.1	1363.0	1352.2	1341.6	1331.3	1321.2	1311.4	1301.7	1292.3	1283.1	1274.1
145	1368.2	1357.1	1346.4	1335.8	1325.6	1315.5	1305.7	1296.1	1286.8	1277.6	1268.6
150	1362.7	1351.7	1341.0	1330.5	1320.2	1310.3	1300.5	1290.9	1281.6	1272.5	1263.5

TABLE II. Pressure function = $(P_1)^{1.02}$ (Discharge pressure, psia)

	0	10	20	30	40	50	60	70	80	90	100
200	222.36	233.70	245.06	256.43	267.80	279.18	290.58	301.99	313.40	324.82	336.25
300	336.25	347.68	359.13	370.58	382.03	393.50	404.97	416.45	427.93	439.42	450.92
400	450.92	462.41	473.92	485.43	496.96	508.47	520.01	531.53	543.07	554.62	566.16
500	566.16	577.72	589.28	600.84	612.41	623.96	635.55	647.13	658.70	670.29	681.88
600	681.88	693.47	705.07	716.67	728.28	739.90	751.50	763.12	774.73	786.36	798.00
700	798.00	809.62	821.24	832.88	844.52	856.17	867.80	879.47	891.11	902.76	914.43
800	914.43	926.08	937.76	949.40	961.08	972.75	984.42	996.09	1007.8	1019.5	1031.1
900	1031.1	1042.8	1054.5	1066.2	1077.9	1089.6	1101.3	1113.0	1124.7	1136.4	1148.2

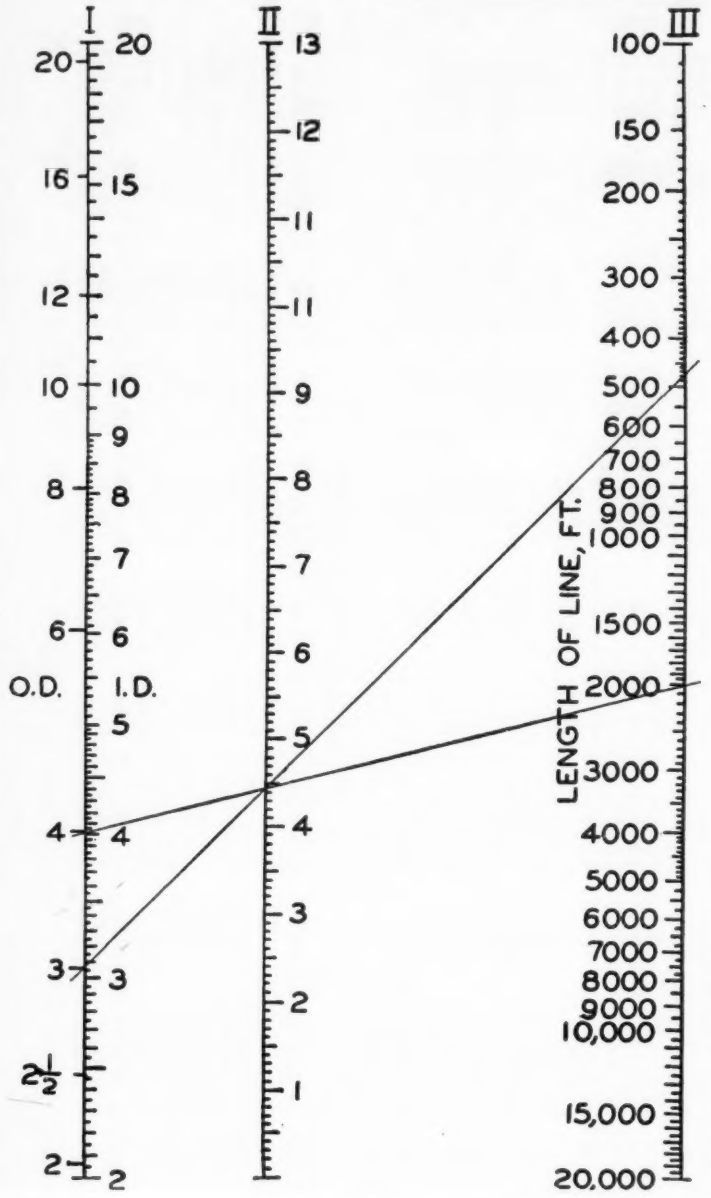
TABLE III. Station spacing function = $\left(\frac{I}{L}\right)^{.501}$ L = Miles between stations

	0	1	2	3	4	5	6	7	8	9	10
0	—	1.00000	0.70223	0.57102	0.49312	0.44008	0.40092	0.37061	0.34628	0.32608	0.30903
10	0.30903	0.29436	0.28159	0.27033	0.26029	0.25129	0.24316	0.23575	0.22898	0.22276	0.21701
20	0.21701	0.21166	0.20670	0.20206	0.19772	0.19367	0.18983	0.18620	0.18278	0.179540	0.17646
30	0.17646	0.17352	0.17076	0.16809	0.16555	0.16312	0.16078	0.15855	0.15641	0.15436	0.15239
40	0.15239	0.15048	0.14861	0.14685	0.14513	0.14350	0.14188	0.14034	0.13885	0.13738	0.13600
50	0.13600	0.13460	0.13330	0.13199	0.13073	0.12954	0.12833	0.12719	0.12608	0.12495	0.12390
60	0.12390	0.12287	0.12183	0.12087	0.11989	0.11895	0.11804	0.11712	0.11624	0.11539	0.11453
70	0.11453	0.11371	0.11288	0.11209	0.11134	0.11058	0.10981	0.10909	0.10840	0.10766	0.10701
80	0.10701	0.10631	0.10565	0.10498	0.10436	0.10373	0.10310	0.10251	0.10192	0.10132	0.10077
90	0.10077	0.10016	0.099604	0.099087	0.098523	0.098001	0.097476	0.096950	0.096469	0.095986	0.095499
100	0.095499	0.095017	0.094537	0.094068	0.093607	0.093149	0.092704	0.092257	0.091823	0.091393	0.090964
110	0.090964	0.090551	0.090134	0.089727	0.089323	0.088926	0.088534	0.088152	0.087767	0.087392	0.087018
120	0.087018	0.086651	0.086286	0.085931	0.085576	0.085228	0.084879	0.084540	0.084200	0.083865	0.083539
130	0.083589	0.083211	0.082888	0.082670	0.082255	0.081945	0.081634	0.081334	0.081033	0.080735	0.080436
140	0.080436	0.080149	0.079860	0.079576	0.079292	0.079012	0.078736	0.078461	0.078190	0.077924	0.077657
150	0.077657	0.077395	0.077131	0.076874	0.076622	0.076368	0.076120	0.075872	0.075629	0.075384	0.075145
160	0.075145	0.074907	0.074666	0.074437	0.074201	0.073973	0.073748	0.073523	0.073296	0.073077	0.072855
170	0.072855	0.072641	0.072425	0.072209	0.071998	0.071786	0.071575	0.071369	0.071169	0.070963	0.070760
180	0.070760	0.070559	0.070364	0.070168	0.069971	0.069780	0.069589	0.069397	0.069212	0.069026	0.068838
190	0.068838	0.068652	0.068472	0.068290	0.068108	0.067933	0.067756	0.067580	0.067403	0.067233	0.067063

TABLE V. F_r = Ratio Function $\left(\frac{r^2-1}{r^2}\right)^{0.510}$

r	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
1.20	0.54621	0.55652	0.56646	0.57598	0.58510	0.59391	0.60235	0.61043	0.61833	0.62589	0.63321
1.30	0.63321	0.64029	0.64714	0.65378	0.66019	0.66647	0.67247	0.67834	0.68402	0.68951	0.69482
1.40	0.69482	0.70008	0.70508	0.71000	0.71479	0.71943	0.72397	0.72840	0.73269	0.73687	0.74095
1.50	0.74095	0.74496	0.74881	0.75265	0.75631	0.75991	0.76342	0.76692	0.77027	0.77354	0.77673
1.60	0.77673	0.77990	0.78294	0.78598	0.78886	0.79174	0.79461	0.79734	0.80000	0.80264	0.80523
1.70	0.80523	0.80780	0.81024	0.81266	0.81508	0.81738	0.81967	0.82194	0.82410	0.82625	0.82838
1.80	0.82838	0.83047	0.83253	0.83449	0.83649	0.83842	0.84029	0.84215	0.84396	0.84575	0.84748
1.90	0.84748	0.84922	0.85094	0.85261	0.85422	0.85588	0.85742	0.85902	0.86054	0.86203	0.86356
2.00	0.86356	0.86495	0.86643	0.86782	0.86922	0.87056	0.87191	0.87326	0.87452	0.87579	0.87706
2.10	0.87706	0.87828	0.87955	0.88071	0.88192	0.88306	0.88422	0.88536	0.88644	0.88755	0.88863

Solution of Complex Pipeline Formulas for Gas Flow



The alignment chart on the left was constructed from the following formula:

$$L_1 = L_2\left(\frac{L_2}{L_1}\right)^{A}$$

Where:

L = length of the line in ft. and

d = diameter of the pipe in in.

Problem: What length of 4-in. diameter pipe will have the same pressure drop as 480 ft. of 3-in. diameter pipe?

Solution: Draw a straight line from the 3-in. pipe diameter on column I to 480 ft. length on column III. The line will intersect column II at 4.45. Then draw a straight line from the 4-in. diameter pipe on column I through 4.45 on column II which will intersect column III at 2000. The length of 4-in. pipe that will have the same pressure drop as 480 ft. of 3-in. pipe is 2000 ft.

In solving similar problems on this chart either internal diameter or external diameter may be used, although care must be taken to use one or the other for both pipes.

The alignment chart on the right side of the page was made from the following formula:

$$d_1 = d_2\left(\frac{d_1}{d_2}\right)^{2.33}$$

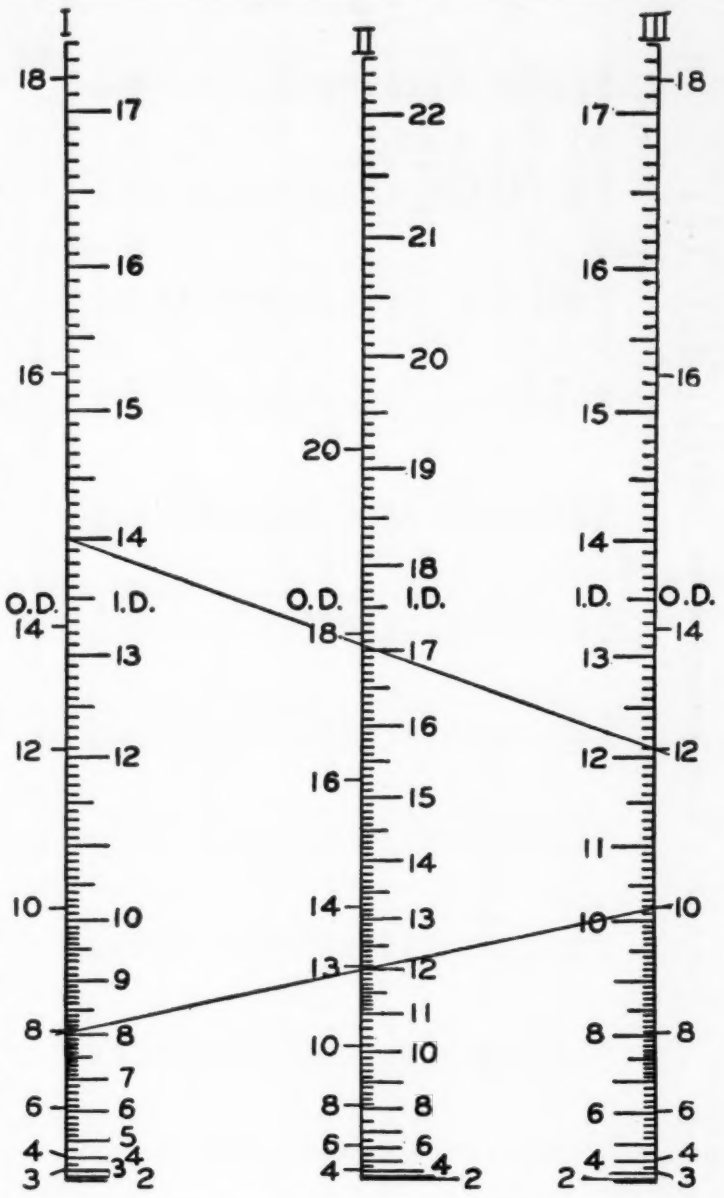
Where:

L = length of the line in ft. and

d = diameter of the pipe in in.

Problem: If an 8-in. and 10-in. external diameter pipe line parallel each other and are connected at each end, what size pipe would have the same capacity as both. (Note: Both sides of the looped lines must be the same length.)

Solution: Draw a straight line from 8 on Column I to 10 on column III. The line will intersect column II at 13, which is the external diameter of a single pipe of equivalent capacity of the 8- and 10-in. lines.



Relative Discharging Capacities of Pipes

TABLE 1—RELATIVE DISCHARGING CAPACITIES OF STANDARD PIPE

Pipe size, in.	Internal diameter d, in.	$d^{5/2}$	Pipe size																
			⅛	¼	⅜	½	¾	1	1¼	1½	2	2½	3	3½	4	5	6	8	10	12
⅛	0.269	0.037530	1.0																	
¼	0.364	0.079938	2.1	1.0																
⅜	0.493	0.17065	4.5	2.1	1.0															
½	0.622	0.30512	8.1	3.8	1.8	1.0														
¾	0.824	0.61634	16	7.7	3.6	2.0	1.0													
1	1.049	1.1270	30	14	6.6	3.7	1.8	1.0												
1¼	1.380	2.2372	60	28	13	7.3	3.6	2.0	1.0											
1½	1.610	3.2890	88	41	19	11	5.3	2.9	1.5	1.0										
2	2.067	6.1426	164	77	36	20	10	5.5	2.7	1.9	1.0									
2½	2.469	9.5786	255	120	56	31	16	8.5	4.3	2.9	1.6	1.0								
3	3.068	16.487	439	206	97	54	27	15	7.4	5.0	2.7	1.7	1.0							
3½	3.548	23.711	632	297	139	78	38	21	11	7.2	3.9	2.5	1.4	1.0						
4	4.026	32.523	867	407	191	107	53	29	15	9.9	5.3	3.4	2.0	1.4	1.0					
5	5.047	57.225	1525	716	335	188	93	51	26	17	9.3	6.0	3.5	2.4	1.8	1.0				
6	6.065	90.589	2414	1133	531	297	147	80	40	28	15	9.5	5.5	3.8	2.8	1.6	1.0			
8	7.981	179.95	4795	2251	1054	590	292	160	80	55	29*	19	11	7.6	5.5	3.1	2.0	1.0		
10	10.020	317.81	8468	3976	1862	1042	516	282	142	97	52	33	19	13	9.8	5.6	3.5	1.8	1.0	
12	12.000	498.83	13292	6240	2923	1635	809	443	223	152	81	52	30	21	15	8.7	5.5	2.8	1.6	1.0

The figure opposite the intersection of any two sizes is the number of smaller size pipes required to equal one of the larger.
*Example: How many 2-in. pipes will it take to equal the discharge of one 8-in. pipe? Answer: 29 2-in. pipes.

TABLE 2—RELATIVE DISCHARGING CAPACITIES OF EXTRA STRONG PIPE

Pipe size, in.	Internal diameter d, in.	$d^{5/2}$	Pipe size																
			⅛	¼	⅜	½	¾	1	1¼	1½	2	2½	3	3½	4	5	6	8	10	12
⅛	0.215	0.021434	1.0																	
¼	0.302	0.060121	2.8	1.0																
⅜	0.423	0.11637	5.4	2.8	1.0															
½	0.546	0.22028	10	4.4	1.9	1.0														
¾	0.742	0.47425	22	9.5	4.1	2.2	1.0													
1	0.957	0.89594	42	18	7.7	4.1	1.9	1.0												
1¼	1.278	1.8464	86	37	16	8.4	3.9	2.1	1.0											
1½	1.500	2.7557	129	55	24	13	5.8	3.1	1.5	1.0										
2	1.939	5.2353	244	104	45	24	11	5.8	2.8	1.9	1.0									
2½	2.323	8.2243	384	164	71	37	17	9.2	4.5	3.0	1.6	1.0								
3	2.900	14.322	668	286	123	65	30	16	7.8	5.2	2.7	1.7	1.0							
3½	3.364	20.756	968	414	178	94	44	23	11	7.5	4.0	2.5	1.4	1.0						
4	3.826	28.633	1336	571	246	130	60	32	16	10	5.5	3.5	2.0	1.4	1.0					
5	4.813	50.821	2371	1014	437	231	107	57	28	18	9.7	6.2	3.5	2.4	1.8	1.0				
6	5.761	79.661	3717	1589	685	362	168	89	43	29	15	9.7	5.6	3.8	2.8	1.6	1.0			
8	7.625	160.55	7490	3203	1380	729	339	179	87	58	31*	20	11	7.7	5.6	3.2	2.0	1.0		
10	9.750	296.83	13849	5922	2551	1348	626	331	161	108	57	36	21	14	10	5.8	3.7	1.8	1.0	
12	11.750	473.25	22079	9442	4067	2148	998	528	256	172	90	58	33	23	17	9.3	5.9	2.9	1.6	1.0

The figure opposite the intersection of any two sizes is the number of smaller size pipes required to equal one of the larger.
*Example: How many 2-in. extra strong pipes will it take to equal the discharge of one 8-in. extra strong pipe? Answer: 31 2-in. pipes.

Explanation: It is frequently desired to know how many pipes of a certain size are equal in discharging capacity to one pipe of a larger size. Under the same head, the velocity is less in the smaller pipe and the discharge varies as the square root of the fifth power of the inside diameter. Expressed as a formula, the

$$\text{Relative discharging capacity} = \frac{\sqrt{d_L^{\,5}}}{\sqrt{d_s^{\,5}}} = \frac{d_L^{\,5/2}}{d_s^{\,5/2}}$$

where d_L = Actual inside diameter of the larger pipe.
d_s = Actual inside diameter of the smaller pipe.

The accompanying tables covering standard, extra strong, and large diameter pipe were calculated by this formula. It is possible by the use of these tables to find directly the number of small pipes which will (under the same head) give the same discharge as one larger pipe, provided the sizes of pipes in question appear in the same table. An example using more than one table follows:

Example: What size of pipe will be required to equal the discharge of the following?

Four 4-in. standard pipes	$=4\times d^{5/2}=4\times 32.523=$	130.092
Two 6-in. standard pipes	$=2\times d^{5/2}=2\times 90.589=$	181.178
Three 8-in. standard pipes	$=3\times d^{5/2}=3\times 179.95=$	539.85
Two 14-in. O.D. × $\frac{7}{8}$-in. wall	$=2\times d^{5/2}=2\times 624.09=$	1248.18
One 18-in. O.D. × ½-in. wall	$= d^{5/2}=$ 1191.6	=1191.6
Total—		3290.9

The nearest figure to 3290.9 is found in table 8 on sheet 2 in the column of factors $d^{5/2}$ corresponding to a pipe about 25½ in. I.D. The $d^{2.5}$ factors on tables P 622.001 (sheets 1, 2, 3, 4, and 5) that were published in *The Petroleum Engineer* in June and July, 1942, may be used in place of the $d^{5/2}$ factors in problems such as the one above.

Table from Bulletin No. 21 by courtesy of National Tube Company.

Chart for Calculating Pipe Storage Capacity

FORMULA

$V = 0.00193\ d^2\ L\ P$

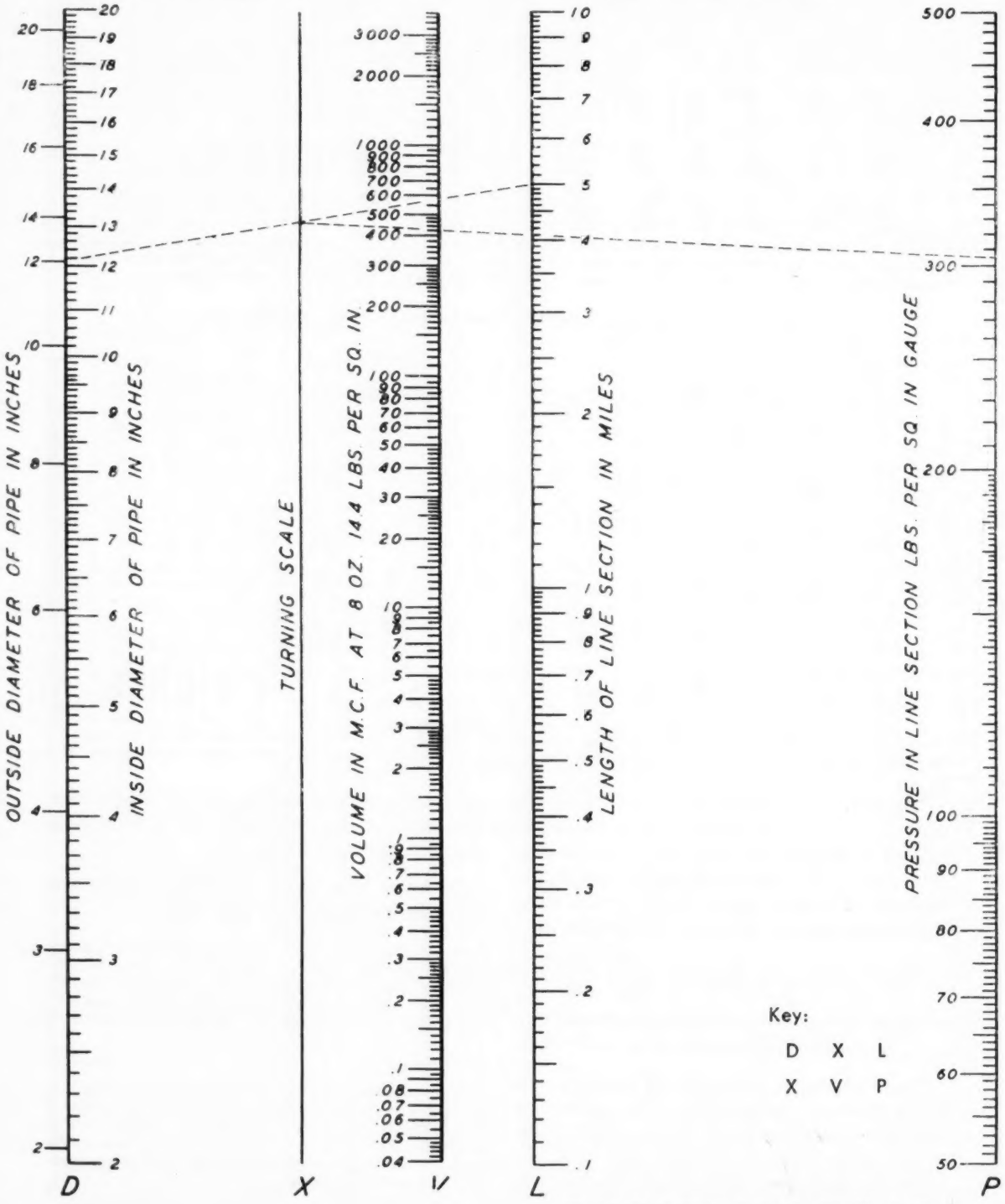
Where:

V = Volume in Mcf at 14.4 psi + 8 oz. (14.9 psia)
d = inside diameter of pipe
L = length of pipe in miles
P = pressure in line section in psig

EXAMPLE

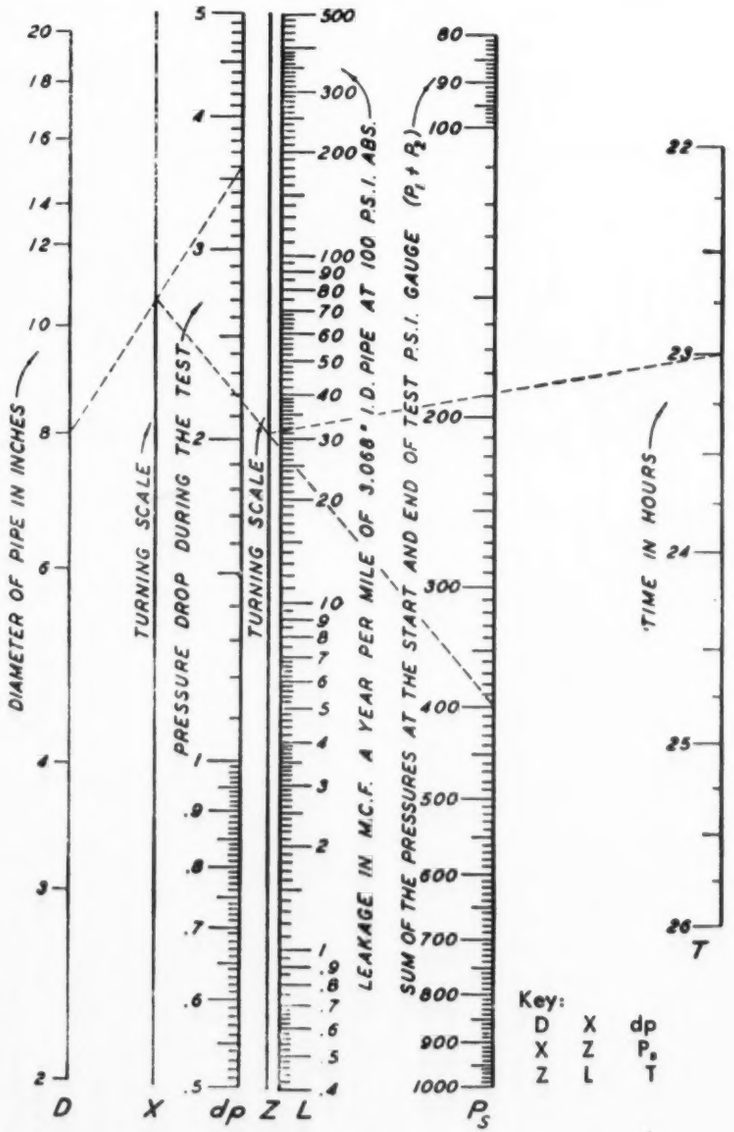
Find volume of gas that would be drained from 5 miles of 12-in. OD line if initial pressure is 305 psig and final pressure is atmospheric.

Solution. Locate 12-in. on scale D and connect to 5 miles on scale L. From the intersection of these lines on turning scale X, draw another line to 305 psig on scale P. Read answer (420 Mcf) on scale V.



—Chart by W. D. Parkes, United Gas Pipe Line Company.

Leakage Test Conversion Chart



Equation:

$$Y = \frac{10{,}750\ D\ (dp)}{P_s\ t}$$

Where:

Y = leakage in M. cu. ft. per year per mile of 3.068 in. I.D. pipe at 100 per sq. in. abs.,

D = internal diameter of pipe, in.,

dp = difference in pressures ($P_1 - P_2$) where P_1 is the absolute pressure in lb. per sq. in. at the start of the test, and P_2 is the absolute pressure in lb. per sq. in. at the end of the test (see table for temperature correction),

P_s = sum of the pressures, and

t = time in hours.

TABLE 1

Temperature correction

Line test pressure lb. per sq. in.	1° Fahrenheit equivalent to lb. per sq. in.
100	0.2
200	0.4
300	0.6
400	0.8
500	1.0
600	1.2
700	1.4
800	1.5
900	1.7
1000	1.9

If the temperature at the end of the test is higher or lower than the temperature at the start of the test, add or subtract the equivalent pressure to the pressure drop during the test.

EXAMPLE

Problem:

Find the leakage in M. cu. ft. per year per mile of 3.068 in. I.D. equivalent pipe at 100 lb. per sq. in. absolute.

Given:

10 miles of 8-in. O.D. pipe. The time required for pressure drop is 23 hours.

	Pressure lb. per sq. in.ga.	Temperature °F.
First set of observations	202	54
Second set of observations	198	53

Solution:

First obtain the pressure drop during the test (202 — 198 = 4 lb. per sq. in.). The pressure drop is corrected for change in temperature by subtracting the equivalent pressure for 1°F. change at 200 lb. per sq. in. (see table) from the pressure drop. (4 — 0.4 = 3.6 lb. per sq. in.)

Locate the pressure drop during the test corrected for temperature, i.e., 3.6 lb. per sq. in. on scale dp, and connect it to 8 in. on scale D. From the intersection of this line on the turning scale X, draw another line to 400 lb. per sq. in. on scale P_s. (202 + 198 = 400 lb. per sq. in.) The intersection of this line on turning scale Z is then connected to 23 on scale T. Read the answer 31.8 M. cu. ft. on scale L.

—Chart by W. D. Parkes, United Gas Pipe Line Company.

Gas Distribution Piping System Standards

(Extracted from ASA Code B31.8—1958)

Scope and Intent

804.1 Section 8 covers the design, fabrication, installation, inspection, testing, and the safety aspects of operation and maintenance of gas transmission and distribution systems, including gas pipelines, gas compressor stations, gas metering and regulating stations, gas mains, and gas services up to the outlet of the customer's meter set assembly. Also included within the scope of this section are gas storage equipment of the closed pipe type fabricated or forged from pipe or fabricated from pipe and fittings, and gas storage lines.

804.2 Requirements of Section 8 also cover the conditions of use of the elements of the piping systems described in 804.1, including, but not limited to, pipe, valves, fittings, flanges, bolting, gaskets, regulators, pressure vessels, pulsation dampeners, and relief valves.

804.3 This Section 8 does not apply to:

(a) Design and fabrication of pressure vessels covered by the ASME code.

(b) Piping with metal temperatures above 450 F or below minus 20 F. (For temperatures above 450 F, ASA B31.1, Section 3, Division A, shall apply. For low temperatures within the range covered by this section, see 814.)

(c) Piping beyond the outlet of the customer's meter set assembly. (See ASA Z21.30 for such piping.)

(d) Piping in oil refineries or natural gasoline extraction plants, gas treating plant piping other than the main gas stream piping in dehydration and all other processing plants installed as part of a gas transmission system, gas manufacturing plants, industrial plants, or mines. (See other applicable sections of ASA B31.1)

(e) Vent piping to operate at substantially atmospheric pressures for waste gases of any kind.

(f) Wellhead assemblies, including control valves, and flow lines between wellhead and trap or separator, or casing and tubing in gas or oil wells.

(g) Proprietary items of equipment, apparatus, or instruments.

(h) Heat exchangers.

(i) Oil or liquid products pipelines.

(j) Prefabricated units which employ plate and longitudinal welds as contrasted to pipe.

804.4 The requirements of Section 8 are adequate for safety under conditions normally encountered in the gas industry. Requirements for abnormal or unusual conditions are not specifically provided for, nor are all details of engineering and construction prescribed. It is intended that all work performed within the scope of this section shall meet or exceed the safety standards expressed or implied herein.

804.5 This section is concerned with:

(a) Safety of the general public.

(b) Employee safety to the extent that it is affected by basic design, quality of the materials and workmanship, and requirements for testing and maintenance of gas transmission and distribution facilities. Existing industrial safety regulations pretaining to work areas, safety devices, and safe work practices are not intended to be supplanted by this code.

804.6 It is not intended that this code be applied retroactively to existing installations insofar as design, fabrication, installation, established operating pressure, and testing are concerned. It is intended, however, that the provisions of this code shall be applicable to the operation, maintenance, and up-rating of existing installations.

This section extracted from American Standard Gas Transmission and Distribution Piping Systems (ASA B31.8—1958)—Section 8 of American Standard Code for Pressure Piping, with the permission of the publisher, The American Society of Mechanical Engineers, 29 West 39th Street, New York 18, New York.

Materials and Equipment

810.1 It is intended that all materials and equipment that will become a permanent part of any piping system constructed under this code shall be suitable and safe for the conditions under which they are used. All such materials and equipment shall be qualified for the conditions of their use by compliance with certain specifications, standards, and special requirements of this code or otherwise as provided herein.

Piping System Components and Fabrication Details

PIPING SYSTEM COMPONENTS

All components of piping systems, including valves, flanges, fittings, headers, special assemblies, etc., shall be designed to withstand operating pressures, and other specified loadings, with unit stresses not in excess of those permitted for comparable material in pipe in the same location and type of service. Components shall be selected that are designed to withstand the field test pressure to which they will be subjected, without failure or leakage, and without impairment of their serviceability.

Valves

831.11 Valves shall be used only in accordance with the service recommendations of the manufacturer. Valves shall conform to American Standards governing minimum wall thickness, materials and dimensions, and may be used in accordance with pressure-temperature ratings contained in the following standards:

ASA B16.5 —Steel Pipe Flanges and Flanged Fittings
API 6D —Specification for Steel Gate, Plug, and Check Valves for Pipe Line Service
MSS SP-44 —Steel Pipe Line Flanges
MSS SP-52 —Cast Iron Pipe Line Valves
ASA B16.24 —Brass or Bronze Flanges and Flanged Fittings.

831.12 Screw-end valves shall be threaded according to the American Standard for Pipe Threads (ASA B2.1) or API Specification for Line Pipe (5L), or API Specification for Threads in Valves, Fittings and Flanges (6A).

831.13 Pressure-reducing devices shall conform to the requirements of this code for valves in comparable service conditions.

Flanges

831.21 **Flange Types and Facings**

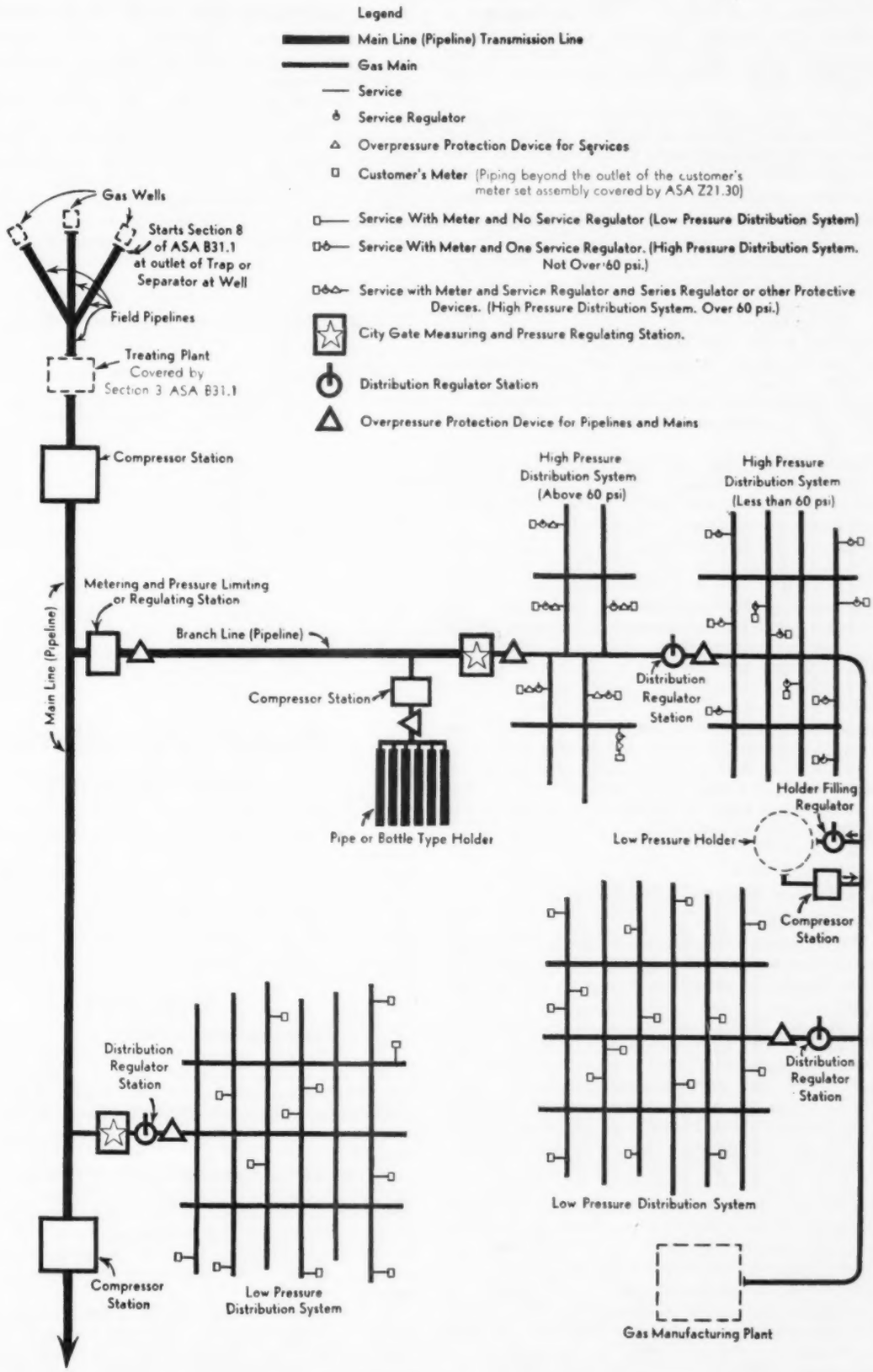
(a) The dimensions and drilling for all line or end flanges shall conform to the following standards:

ASA B-16 Series — (For Iron and Steel)
MSS SP-44 — Steel Pipe Line Flanges
Appendix H — Light-Weight Steel Flanges
ASA B16.24 — Brass or Bronze Flanges and Flanged Fittings.

Flanges cast or forged integral with pipe, fittings or valves will be permitted in sizes and for the maximum service ratings covered by the Standards listed above, subject to the facing, bolting and gasketing requirements of this paragraph and 831.22 and 831.23.

DIAGRAM SHOWING SCOPE OF SECTION 8 OF ASA B31

Facilities indicated by Solid Lines are within the Scope of Section 8 of ASA B31


Legend
Main Line (Pipeline) Transmission Line
Gas Main
Service
Service Regulator
Overpressure Protection Device for Services
Customer's Meter (Piping beyond the outlet of the customer's meter set assembly covered by ASA Z21.30)
Service With Meter and No Service Regulator (Low Pressure Distribution System)
Service With Meter and One Service Regulator. (High Pressure Distribution System. Not Over 60 psi.)
Service with Meter and Service Regulator and Series Regulator or other Protective Devices. (High Pressure Distribution System. Over 60 psi.)
City Gate Measuring and Pressure Regulating Station.
Distribution Regulator Station
Overpressure Protection Device for Pipelines and Mains
Gas Wells
Starts Section 8 of ASA B31.1 at outlet of Trap or Separator at Well
Field Pipelines
Treating Plant Covered by Section 3 ASA B31.1
Compressor Station
Main Line (Pipeline)
Metering and Pressure Limiting or Regulating Station
Branch Line (Pipeline)
Compressor Station
Pipe or Bottle Type Holder
High Pressure Distribution System (Above 60 psi)
High Pressure Distribution System (Less than 60 psi)
Distribution Regulator Station
Holder Filling Regulator
Low Pressure Holder
Compressor Station
Distribution Regulator Station
Low Pressure Distribution System
Distribution Regulator Station
Compressor Station
Low Pressure Distribution System
Gas Manufacturing Plant

(b) Screwed companion flanges which comply with the B16 group of ASA Standards will be permitted in sizes and for maximum service ratings covered by these standards.

(c) Lapped flanges will be permitted in sizes and pressure standards established in the American Standard ASA B16.5.

(d) Slip-on welding flanges will be permitted in sizes and pressure standards established in American Standard ASA B16.5 and MSS SP-44. Slip-on flanges of rectangular section may be substituted for hubbed slip-on flanges provided the thickness is increased as required to produce equivalent strength as determined by calculations made in accordance with Section VIII, Unfired Pressure Vessels, of the ASME Boiler and Pressure Vessel Code.

(e) Welding neck flanges will be permitted in sizes and pressure standards established in American Standard ASA B16.5 and MSS SP-44. The bore of the flange should correspond to the inside diameter of the pipe used.

(f) Cast iron and steel flanges shall have contact faces finished in accordance with MSS Standard Finishes for Contact Faces of Connecting-End Flanges of Ferrous Valves and Fittings, SP-6.

(g) Non-ferrous flanges shall have contact faces finished in accordance with American Standard ASA B16.24.

(h) 25 psi and Class 125 cast-iron integral or screwed companion flanges may be used with a full face gasket or with a flat ring gasket extending to the inner edge of the bolt holes. When using a full-face gasket, the bolting may be of heat-treated carbon steel (ASTM A-261), or alloy steel (ASTM A-193). When using a ring gasket, the bolting shall be of carbon steel equivalent to ASTM A-307, Grade B without heat treatment other than stress relief.

(i) When bolting together two Class 250 integral or screwed companion cast-iron flanges, having 1/16-in. raised faces, the bolting shall be of carbon steel equivalent to ASTM A-307 Grade B, without heat treatment other than stress relief.

(j) 150 psi steel flanges may be bolted to Class 125 cast-iron flanges. When such construction is used, the 1/16-in. raised face on the steel flange shall be removed. When bolting such flanges together using a flat ring gasket extending to the inner edge of the bolt holes, the bolting shall be carbon steel equivalent to ASTM A-307 Grade B, without heat treatment other than stress relief. When bolting such flanges together using a full face gasket, the bolting may be heat treated carbon steel (ASTM A-261) or alloy steel (ASTM A-193).

(k) 300 psi steel flanges may be bolted to Class 250 cast-iron flanges. Where such construction is used, the bolting shall be of carbon steel, equivalent to ASTM A-307 Grade B, without heat treatment other than stress relief. Good practice indicates that the raised face on the steel flange should be removed, but also in this case, bolting shall be of carbon-steel equivalent to ASTM A-307 Grade B.

Fittings Other Than Valves and Flanges

831.31 **Standard Fittings**

(a) The minimum metal thickness of flanged or screwed fittings shall not be less than specified for the pressures and temperatures in the Applicable American Standards or the MSS Standard Practice.

(b) Steel butt-welding fittings (not flanged) shall comply with the American Standard for Steel Butt-Welding Fittings (ASA B16.9) and shall have pressure and temperature ratings based on stresses for pipe of the same or equivalent material. To insure adequacy of fitting design, the actual bursting strength of fittings shall at least equal the computed bursting strength of pipe of the designated material and wall thickness. Mill hydrostatic testing of factory made steel butt-welding fittings is not required, but all such fittings shall be capable of withstanding a field test pressure equal to the test pressure established by the manufacturer, without failure or leakage, and without impairment of their serviceability.

(c) Steel socket-welding fittings shall comply with American Standard for Steel Socket-Welding Fittings (ASA B16.11).

831.32 **Special Fittings.** When special cast, forged, wrought, or welded fittings are required to dimensions differing from those of regular shapes specified in the applicable ASA and MSS Standards, the provisions of 807 shall apply.

831.33 **Branch Connections.**

(a) Welded branch connections on steel pipe must meet the design requirements of 831.4 and 831.5.

(b) Threaded taps in cast iron pipe are permitted, without reinforcement, to a size not more than 25 percent of the nominal diameter of the pipe, except that 1¼ in. taps are permitted in 4 in. pipe. Larger taps shall be covered by a reinforcing sleeve.

(c) Mechanical fittings may be used for making hot taps on pipelines and mains; provided they are designed for the operating pressure of the pipeline or main, and are suitable for the purpose.

EXPANSION AND FLEXIBILITY

832.1 This section is applicable to above ground piping only and covers all classes of materials permitted by this code up to temperatures no greater than 450 F.

832.2 **Amount of Expansion.** The thermal expansion of the more common materials used for piping shall be determined from Table 832.21. The expansion to be considered is the difference between the expansion for the maximum expected operating temperature and that for the expected average erection temperature. For materials not included in this table, or for precise calculations, reference shall be made to authoritative source data, such as publications of the National Bureau of Standards.

TABLE 832.21. Thermal Expansion of Piping Materials.

Carbon and low alloy high tensile steel and wrought iron

Temperature Degree F	Total expansion in inches per 100 ft above 32 F
32	0.
60	0.2
100	0.5
125	0.7
150	0.9
175	1.1
200	1.3
225	1.5
250	1.7
300	2.2
350	2.6
400	3.0
450	3.5

Design, Installation, and Testing

840.1 **General Provisions.** The design requirements of this code are intended to be adequate for public safety under all conditions usually encountered in the gas industry. However, special conditions that may cause additional stress in any part of a line or its appurtenances shall be provided for, using good engineering practice. Examples of such special conditions include: Long self-supported spans, unstable ground, mechanical or sonic vibrations, weight of special attachments, and thermal forces other than seasonal.

STEEL PIPE

841.001 **Population Density Indices**

(a) Two population density indices, determined at the time of initial construction, are used to classify locations for design and testing purposes: (1) The one-mile density index, which applies to any specific mile of pipeline; and (2) the ten-mile density index, which applies to any specific ten-mile length of pipeline.

(b) To determine the one-mile density indices for a proposed pipeline, lay out a zone one-half mile wide along the route of the pipeline with the pipeline on the center line of this zone. Divide the zone into lengths, each containing one mile of pipeline. Count the number of buildings intended for human occupancy in each of these lengths. These numbers are the one-mile indices for the pipeline.

(c) To determine the ten-mile density indices for any given ten-mile length of pipeline, proceed as follows: Add the one-mile density indices for the ten-mile section. In case a one-mile index equals or exceeds 20, it is to be included in the sum as 20. Divide the sum thus obtained by 10. The quotient is the ten-mile density index for the section.

CLASSIFICATION OF STEEL PIPE CONSTRUCTION[1]

Four types of steel pipe construction are prescribed in this code. The distinguishing characteristics of each type and the locations in which each type shall be used are as follows:

	Type A construction	Type B construction	Type C construction	Type D construction
A. Characteristics 1. Design Factor F (See 841.11)	.72	.60	.50	.40
B. Locations where type of construction shall be used.	(a) On private rights of way in class 1 locations. (b) Parallel encroachments on: Privately owned roads in class 1 locations. Unimproved roads in class 1 locations. (c) Crossings without casings of privately owned roads in class 1 locations. (d) Crossings in casings of unimproved public roads, hard-surfaced roads, highways or public streets and railroads in class 1 locations.	(a) On private rights of way in class 2 locations. (b) Parallel encroachments on: Privately owned roads in class 2 locations. Unimproved public roads in class 2 locations. Hard surfaced roads, highways or public streets and railroads in class 1 locations and class 2 locations. (c) Crossings without casings of: Privately owned roads in class 2 locations. Unimproved public roads in class 2 locations. Hard surfaced roads, highways or public streets and railroads in class 1 locations. (d) Crossings in casings of: Hard surfaced roads, highways or public streets and railroads in class 2 locations. (e) On bridges in class 1 and class 2 locations. (See 841.143) (f) Fabricated assemblies in pipe lines in location classes 1 and 2. (See 841.142)	(a) On private rights of way in class 3 locations. (b) Parallel encroachments on: Privately owned roads in class 3 locations. Unimproved public roads in class 3 locations. Hard surfaced roads, highways or public streets and railroads in class 3 locations. (c) Crossings without casings of: Privately owned roads in class 3 locations. Unimproved public roads in class 3 locations. Hard surfaced roads, highways or public streets and railroads in class 2 and and 3 locations. (d) Compressor station piping.	(a) In all locations in location class 4.

(1) It is necessary to distinguish between construction types, as defined by Section A of this table, and location classes, as defined in 841.01, to avoid confusion. If pipelines or mains are located in private rights of way, the code prescribes that Type A construction be used in Class 1 locations, Type B construction in Class 2 locations, Type C construction in Class 3 locations, and Type D construction in Class 4 locations. There are many exceptions to this association of Class 1 with Type A, etc., however, as Table 841.02 shows, most of which are cases where pipelines or mains are located in highways or on bridges, etc.

Classification of Locations

841.011 **Class 1 Locations**

Class 1 locations include waste lands, deserts, rugged mountains, grazing land, and farm land, and combinations of these; provided, however, that:

(a) The ten-mile density index for any section of the line is 12 or less.

(b) The one-mile density, index for any one mile of line is 20 or less.[1]

841.012 **Class 2 Locations**

Class 2 locations include areas where the degree of development is intermediate between Class 1 locations and Class 3 locations. Fringe areas around cities and towns, and farm or industrial areas where the one-mile density index exceeds 20 or the ten-mile density index exceeds 12 fall within this location class.

841.013 **Class 3 Locations**

Class 3 locations include areas subdivided for residential or commercial purposes where, at the time of construction of the pipeline or piping system, 10 percent or more of the lots abutting on the street or right-of-way in which the pipe is to be located are built upon, and a Class 4 classification is not called for. This permits classifying as Class 3, areas completely occupied by commercial or residential buildings with the prevalent height of three stories or less.

841.014 **Class 4 Locations**

Class 4 locations include areas where multistory[2] buildings are prevalent, and where traffic is heavy or dense and where there may be numerous other utilities underground.

841.015 It should be emphasized that *Location Class* (1, 2, 3 or 4), as described in the foregoing paragraphs, is defined as the general description of a geographic area having certain characteristics as a basis for prescribing the types of construction and methods of testing to be used in those locations or in areas that are respectively comparable. A numbered Location-Class refers only to the geography of that location or a similar area, and does not necessarily indicate that a correspondingly numbered Construction-Type will suffice for all construction in that particular location or area. Example: In Location Class 1, all aerial crossings require Type B construction. (See 841.143)

[1] It is not intended here that a full mile of lower-stress-level pipeline shall be installed if there are physical barriers or other factors that will limit the further expansion of the more densely populated area to a total distance of less than 1 mile. It is intended, however, that where no such barriers exist, ample allowance shall be made in determining the limits of the lower-stress design to provide for probable further development in the area.

[2] Multistory means 4 or more "floors" above ground including the first or ground floor. The depth of basements or number of basement floors is immaterial.

CONSTRUCTION TYPES REQUIRED FOR PARALLEL ENCROACHMENTS OF PIPELINES AND MAINS ON ROADS AND RAILROADS

Kind of Thoroughfare	Construction Type Required			
	Location class 1	Location class 2	Location class 3	Location class 4
(a) Privately owned roads	Type A	Type B	Type C	Type D
(b) Unimproved public roads	Type A	Type B	Type C	Type D
(c) Hard surface roads, highways or public streets and railroads	Type B	Type B	Type C	Type D

CONSTRUCTION TYPES REQUIRED FOR PIPELINES AND MAINS CROSSING ROADS AND RAILROADS

Kind of Thoroughfare	Construction Type Required			
	Location class 1	Location class 2	Location class 3	Location class 4
(a) Privately owned roads	Type A without casing	Type B without casing	Type C without casing	Type D without casing
(b) Unimproved public roads	Type A with casing Type B without casing	Type B without casing	Type C without casing	Type D without casing
(c) Hard surface roads, highways or public streets and railroads	Type A with casing Type B without casing	Type B with casing Type B without casing	Type C without casing	Type D without casing

841.016 When classifying locations for the purpose of determining the type of pipeline construction and testing that should be prescribed, due consideration shall be given to the possibility of future development of the area. If at the time of planning a new pipeline this future development appears likely to be sufficient to change the location class, this should be taken into consideration in the design and testing of the proposed pipeline.

It is also anticipated that some increase in population density will occur in all areas after a line is constructed, and this possibility has been taken into account in establishing the design, construction, and testing procedures for each location class.

841.1 **Steel Pipe Design Formula.** The design pressure for steel gas piping system or the nominal wall thickness for a given design pressure shall be determined by the following formula:

$$P = \frac{2St}{D} \times F \times E \times T$$

(For exceptions see 841.4)

Where:

P = Design pressure, psig

S = Specified minimum yield strength, psi, stipulated in the specifications under which the pipe was purchased from the manufacturer or determined in accordance with 811.27 H. The specified minimum yield strengths of some of the more commonly used piping steels, whose specifications are incorporated by reference herein, are tabulated for convenience in Appendix "C." For special limitation on S see 841.14 (e) and (f).

D = Nominal outside diameter of pipe, inches.

t = Nominal wall thickness, inches.

F = Construction type design factor obtained from 841.11.

E = Longitudinal joint factor obtained from 841.12.

T = Temperature derating factor obtained from Table 841.13.

841.14 **Limitations of Pipe Design Values**

(a) P for furnace butt welded pipe shall not exceed the restrictions of 841.1 or 60 percent of the mill test pressure, whichever is the lesser.

(b) P shall not exceed 85 percent of the mill test pressure for all other pipes; provided, however, that pipe, mill tested to a pressure less than 85 percent of the pressure required to produce a stress equal to the specified minimum yield, may be retested with a mill type hydrostatic test or tested in place after installation. In the event the pipe is retested to a pressure in excess of the mill test pressure, then P shall not exceed 85 percent of the retest pressure rather than the initial mill test pressure. It is mandatory to use a liquid as the test medium in all tests in place after installation where the test pressure exceeds the mill test pressure. This paragraph is not to be construed to allow an operating pressure or design pressure in excess of that provided for by 841.1.

(c) Transportation, installation or repair of pipe shall not reduce the wall thickness at any point to a thickness less than 90 percent of the nominal wall thickness as determined by 841.1 for the design pressure to which the pipe is to be subjected.

(d) "t" shall not be less than shown in Table 841.141.

(e) When pipe that has been cold worked for the purpose of meeting the specified minimum yield strength is heated to 600 F or higher (welding excepted), the maximum allowable pressure at which it can be used shall not exceed 75 percent of the value obtained by use of the steel pipe design formula given in 841.1.

(f) In no case where the code refers to the specified minimum value of a physical property can the actual value of the property be substituted in design calculations, unless the actual is less than the specified minimum. Table 841.141.

841.142 **Fabricated Assemblies.** When fabricated assemblies, such as connections for separators, main line valve assemblies, cross-connections, river crossing headers, etc., are to be installed in areas defined as location Class 1, Type B construction is required throughout the assembly, and for a distance of 5 pipe diameters in each direction beyond the last fittings. Transition pieces at the end of an assembly and elbows used in place of pipe bends are not considered as fittings under the requirements of this paragraph.

841.143 Pipelines or mains supported by railroad, vehicular, pedestrian, or pipeline bridges shall be in accordance with the construction type prescribed for the area in which the bridge is located, except that in Class 1 locations Type B construction shall be used.

Table 841.11
Values of Design Factor "F"

Construction Type (See 841.02)	Design Factor F
Type—A	0.72
Type—B	0.60
Type—C	0.50
Type—D	0.40

Table 841.12
Longitudinal Joint Factor "E"

Spec. Number	Pipe Class	E Factor
ASTM A53	Seamless	1.00
	Electric Resistance Welded	1.00
	Furnace Lap Welded	.80
	Furnace Butt Welded	.60
ASTM A106	Seamless	1.00
ASTM A134	Electric Fusion Arc Welded	.80
ASTM A135	Electric Resistance Welded	1.00
ASTM A139	Electric Fusion Welded	.80
ASTM A155	Electric Fusion Arc Welded	1.00
ASTM A381	Double Submerged Arc Welded	1.00
API 5L	Seamless	1.00
	Electric Resistance Welded	1.00
	Electric Flash Welded	1.00
	Furnace Lap Welded	.80
	Furnace Butt Welded	.60
API 5LX	Seamless	1.00
	Electric Resistance Welded	1.00
	Electric Flash Welded	1.00
	Submerged Arc Welded	1.00

Table 841.13
Temperature Derating Factor "T" for Steel Pipe

Temperature Degrees Fahrenheit	Temperature Derating Factor "T"
250 F or less	1.000
300 F	0.967
350 F	0.933
400 F	0.900
450 F	0.867

Note: For intermediate temperatures interpolate for derating factor.

Table 841.141
Least Nominal Wall Thicknesses (Inches)

Nominal Diameter (Inches)	Location Classes (Note 1)		Compressor Stations	
	1	2, 3, & 4		
⅛	0.068	0.068	0.095	Threaded or Plain End
¼	0.088	0.088	0.119	
⅜	0.091	0.091	0.126	
½	0.109	0.109	0.147	
¾	0.113	0.113	0.154	
1	0.133	0.133	0.179	
1¼	0.140	0.140	0.191	
1½	0.145	0.145	0.200	
2	0.154	0.154	0.218	
2½	0.103	*0.125	0.203	Threaded or Plain End
3	0.104	*0.125	0.216	
3½	0.104	*0.125	0.226	
4	0.104	*0.125	0.237	
5	0.104	*0.125	0.250	Plain End Only
6	0.104	0.156	0.250	
8	0.104	0.172	0.250	
10	0.104	0.188	0.250	
12	0.104	0.203	0.250	
14	0.134	0.210	0.250	
16	0.134	0.219	0.250	
18	0.134	0.250	0.250	
20	0.134	0.250	0.250	
22, 24, 26	0.164	0.250	0.250	
28, 30	0.164	0.281	0.281	
32, 34, 36	0.164	0.312	0.312	

Note 1: If threaded pipe is to be used in those sizes for which least nominal wall thicknesses are given for "plain end pipe only," those sizes marked by * shall be increased as follows: 2½ in. to 0.203, 3 in. to 0.216, 3½ in. to 0.226, 4 in. to 0.237, 5 in. to 0.258, and add 0.100 in. to all other wall thicknesses given in Table 841.141.

841.15 **Protection of Pipelines and Mains from Hazards.** When pipelines and mains must be installed where they will be subjected to natural hazards, such as washouts, floods, unstable soil, land slides, or other conditions which may cause serious movement of, or abnormal loads on the pipeline, reasonable precaution shall be taken to protect the pipeline, such as increasing the wall thickness, constructing revetments, erosion prevention, installing anchors, etc. Where pipelines and mains are exposed, such as at spans, trestles, and bridge crossings, the pipelines and mains shall be reasonably protected by distance or barricades from accidental damage by vehicular traffic or other causes.

841.16 **Cover and Casing Requirements Under Railroads, Roads, Streets or Highways.**

(a) All buried pipelines, mains, and casings when used, shall be installed with a minimum cover of 24 in. unless otherwise provided herein.

(b) Buried pipelines and mains operating at hoop stresses of less than 20 percent of the specified minimum yield strength and located within private rights-of-way, private thoroughfares, sidewalks or parkways may be installed with less than the minimum cover of 24 in. if it appears that external damage to the pipe will not be likely to result.

(c) Abandoned pipe having a cover less than 24 in. may be used as a casing or conduit for pipelines and mains operating at hoop stresses less than 20 percent of the specified minimum yield strength.

(d) Buried pipelines and mains installed in areas where farming or other operations might result in deep plowing, or in thoroughfares or other locations where grading is done, or where the area is subject to erosion, should be provided with more cover than the minimum otherwise required.

(e) Where it is impractical to comply with the provisions of 841.16(a) and it is necessary to prevent damage from external loads, the pipe shall be cased or bridged.

(f) Casings shall be designed to withstand the superimposed loads. Where there is a possibility of water entering the casing, the ends of the casing shall be sealed. If the end sealing is of a type that will retain the full pressure of the pipe, the casing shall be designed for the same pressure as the pipe but according to Type A construction requirements. Venting of sealed casings is not mandatory; however, if vents are installed they should be protected from the weather to prevent water from entering the casing.

841.161 **Clearance Between Pipeline or Mains and Other Underground Structures.**

There should be at least 2 in. clearance wherever possible between any gas main or pipeline and any other underground structure not used in conjunction with the pipeline or main. When this clearance cannot be attained, other suitable precautions to protect the pipe shall be taken, such as the installation of insulating material, installation of casing, etc.

841.171 **Corrosion Factors for Design of Steel Pipelines, and Mains.**

(a) The design procedures prescribed by this code for pipelines and mains are applicable without modification only when the gas transported is substantially noncorrosive; and the soil in which the pipeline is installed is either substantially noncorrosive, or suitable steps are taken to mitigate external corrosion.

(b) If a corrosive gas is to be transported, or if suitable means of preventing external corrosion in corrosive soils are not to be provided, the thickness of the pipe shall be increased to provide an allowance for corrosion. The minimum corrosion allowances to be provided in any such case shall not be less than .05 in. for external corrosion and .075 in. for internal corrosion. If both external and internal corrosion are to be expected, add both allowances.

(c) If the thickness obtained by adding the required allowance to the thickness computed by equation 841.1 does not exceed the least allowable wall thickness prescribed in Table 841.141, at least the thickness given in that table shall be used.

(d) If the maximum hoop stress due to gas pressure is less than 20 percent of the specified minimum yield strength, allowance for corrosion is not mandatory. However, the installation in corrosive soil of unprotected pipe with wall thickness as thin as permitted by Table 841.141 is not recommended even for low-pressure distribution systems.

841.172 **Internal Corrosion Criteria**

(a) For the purposes of this code, any fuel gas of commercial grade, the water dew point of which is at all times below pipeline temperature, shall be considered to be substantially noncorrosive unless experience with it has indicated otherwise.

(b) Some fuel gases may be substantially noncorrosive even though their water dew point exceeds pipeline temperatures. Such gas shall, however, be assumed to be noncorrosive only if proven so by careful tests or experience.

841.173 **External Corrosion Criteria.** Suitable investigation shall be made, and if it indicates that protection from external corrosion is needed, steel pipelines or mains shall be protected by any recognized method or combination of methods, such as coating with protective material, application of cathodic protection, and electrical bonding or isolation of sections.

Installation of Steel Pipelines and Mains

841.21 **Construction Specifications.** All construction work performed on piping systems in accordance with the requirements of this code shall be done under construction specifications. Preferably the construction specifications shall cover all phases of the work and should be in sufficient detail to cover the requirements of this code.

Inspection Provisions

841.221 The operating company shall make provision for suitable inspection. Inspectors shall be qualified by either experience or training.

841.222 The installation inspection provisions for pipelines and other facilities to operate at hoop stresses of 20 percent or more of the specified minimum yield strength should be adequate either to make possible the following inspections at sufficiently frequent intervals or to do other things that will assure good quality of workmanship.

(a) Inspect the surface of the pipe for serious surface defects just prior to the coating operation. See 841.242(a).

(b) Inspect the surface of the coated pipe as it is lowered into the ditch to find coating lacerations that indicate the pipe might have been damaged after being coated. Damage during the lowering-in process should be found during this inspection.

(c) Inspect the fit-up of the joints before the weld is made.

(d) Visually inspect the stringer beads before subsequent beads are applied.

(e) Inspect the completed welds before they are covered with coating.

(f) Inspect the condition of the ditch bottom just before the pipe is lowered in.

(g) Inspect the fit of the pipe to the ditch before backfilling.

(h) Inspect all repairs, replacements or changes ordered before they are covered up.

(i) Perform such special tests and inspections as are required by the specifications, such as the radiographing of a portion of the welds and the electrical testing of the protective coating.

841.223 The inspector shall have authority to order the removal and replacement of any section that fails to meet the standards of this code.

Miscellaneous Operations Involved in the Installation of Steel Pipelines and Mains

841.271 **Handling, Hauling and Stringing.** Care should be taken in the selection of the handling equipment and in handling, hauling, unloading, and placing the pipe so as not to damage the pipe.

841.272 **Installation of Pipe in the Ditch.** On pipelines operating at stresses of 20 percent or more of the specified minimum yield strength, it is very important that stresses induced into the pipeline by construction be minimized. This includes grading the ditch so that the pipe has a firm substantially continuous bearing on the bottom of the ditch. The pipe shall fit the ditch without the use of external force to hold it in place until the backfill is completed. When long sections of pipe that have been welded alongside the ditch are lowered in, care shall be exercised so as not to jerk the pipe or impose any strains that may kink or put a permanent bend in the pipe. Slack loops are not prohibited by this paragraph where laying conditions render their use advisable.

841.273 **Backfilling.**

(a) Backfilling should be performed in a manner to provide firm support under the pipe.

(b) If there are large rocks in the material to be used for backfill, care should be used to prevent damage to the coating, by such means as the use of rock shield material, or by making the initial fill with rock free material to a sufficient depth over the pipe to prevent rock damage.

(c) Where flooding of the trench is done to consolidate the backfill, care shall be exercised to see that the pipe is not floated from its firm bearing on the trench bottom.

841.274 **Hot Taps.** All hot taps shall be installed by trained and experienced crews.

Precautions to Avoid Explosions of Gas-Air Mixtures or Uncontrolled Fires During Construction Operations

841.281 Operations such as gas or electric welding and cutting with cutting torches can be safely performed on pipelines and mains and auxiliary equipment, provided that they are completely full of gas, or air that is free from combustible material. Steps shall be taken to prevent a mixture of gas and air at all points where such operations are to be performed.

841.282 When a pipeline or main can be kept full of gas during a welding or cutting operation, the following procedures are recommended:

(a) Keep a slight flow of gas moving toward the point where cutting or welding is being done.

(b) The gas pressure at the site of the work shall be controlled by suitable means.

(c) Close all slots or open ends immediately after they are cut, with tape, and/or tightly fitted canvas or other suitable material.

(d) Do not permit two openings to remain uncovered at the same time. This is doubly important if the two openings are at different elevations.

841.283 No welding or acetylene cutting should be done on a pipeline, main or auxiliary apparatus that contains air if it is connected to a source of gas, unless a suitable means has been provided to prevent the leakage of gas into the pipeline or main.

841.284 In situations where welding or cutting must be done on facilities which are filled with air and connected to a source of gas and the precautions recommended above cannot be taken, one or more of the following precautions, depending upon circumstances at the job, are suggested:

(a) Purging of the pipe or equipment upon which welding or cutting is to be done, with combustible gas or inert gas.

(b) Testing of the atmosphere in the vicinity of the zone to be heated before the work is started and at intervals as the work progresses, with a combustible gas indicator or by other suitable means.

(c) Careful verification before the work starts that the valves that isolate the work from a source of gas do not leak.

841.285 **Purging of Pipelines and Mains.**

(a) When a pipeline or main full of air is placed in service, the air in it can be safely displaced with gas provided that a moderately rapid and continuous flow of gas is introduced at one end of the line and the air is vented out the other end. The gas flow should be continued without interruption until the vented gas is free from air. The vent should then be closed.

(b) In cases where gas in a pipeline or main is to be displaced with air and the rate at which air can be supplied to the line is too small to make a procedure similar to, but the reverse of that described in 841.285(a) feasible, a slug of inert gas should be introduced to prevent the formation of an explosive mixture at the interface between gas and air. Nitrogen or carbon dioxide can be used for this purpose.

(c) If a pipeline or main containing gas is to be removed, the operation may be carried out in accordance with 841.282 or the line may be first disconnected from all sources of gas and then thoroughly purged with air, water or with inert gas before any further cutting or welding is done.

(d) If a gas pipeline or main or auxiliary equipment is to be filled with air after having been in service and there is a reasonable possibility that the inside surfaces of the facility are wetted with a volatile inflammable liquid, or if such liquids might have accummulated in low places, purging procedures designed to meet this situation shall be used. Steaming of the facility until all combustible liquids have been evaporated and swept out is recommended. Filling of the facility with an inert gas and keeping it full of such gas during the progress of any work that might ignite an explosive mixture in the facility is an alternatve recommendation. The possibility of striking static sparks within the facility must not be overlooked as a possible source of ignition.

841.286 Whenever the accidental ignition in the open air of a gas-air mixture might be likely to cause personal injury or property damage, precautions shall be taken as, for example:

(a) Prohibit smoking and open flames in the area, and

(b) Install a metallic bond around the location of cuts in gas pipes to be made by other means than cutting torches, and

(c) Take precautions to prevent static electricity sparks, and

(d) Provide a fire extinguisher of a class approved by the National Fire Protection Association, or the National Board of Fire Underwriters.

Testing After Construction

841.31 **General Provisions.** All pipelines, mains and services shall be tested after construction, except as follows:

Tie-ins. Because it is sometimes necessary to divide a pipeline or main into test sections and install test heads, connecting piping, and other necessary appurtenances for testing, it is not required that the tie-in sections of pipe be tested.

Test Requirements

841.41 **Test Required to Prove Strength of Pipelines and Mains to Operate at Hoop Stresses of 30 Percent or More of the Specified Minimum Yield Strength of the Pipe.**

841.411 All pipelines and mains to be operated at a hoop stress of 30 percent or more of the specified minimum yield strength of the pipe shall be given a field test to prove strength after construction and before being placed in operation.

Table 841.412(d)

Test Requirements for Pipelines and Mains to Operate at Hoop Stresses of 30 Percent or More of the Specified Minimum Yield Strength of the Pipe

1	2	3	4	5
		Prescribed Test Pressure		Maximum Allowable Operating Pressure, the lesser of
Location Class	Permissible Test Fluid	Minimum	Maximum	
1	Water	1.1 x m.o.p.	none	t.p.÷ 1.1
	Air	1.1 x m.o.p.	1.1 x d.p.	or d.p.
	Gas	1.1 x m.o.p.	1.1 x d.p.	
2	Water	1.25 x m.o.p.	None	t.p.÷1.25
	Air	1.25 x m.o.p.	1.25 x d.p.	or d.p.
3	Water	1.40 x m.o.p.	None	t.p.÷1.40 or d.p.
4	Water	1.40 x m.o.p.	None	t.p.÷1.40 or d.p.

m.o.p. = maximum operating pressure (not necessarily the maximum allowable operating pressure)
d.p. = design pressure
t.p. = test pressure

Note 1. This table brings out the relationship between test pressures and maximum allowable operating pressures subsequent to the test. If an operating company decides that the maximum operating pressure will be less than the design pressure a corresponding reduction in prescribed test pressure may be made as indicated in Column 3. However, if this reduced test pressure is used the maximum operating pressure cannot later be raised to the design pressure without retesting the line to the test pressure precribed in Column 4. See 805.14, 845.22 and 845.23.

841.412 (a) Pipelines and mains located in Location Class 1 shall be tested either with air or gas to 1.1 times the maximum operating pressure or hydrostatically to at least 1.1 times the maximum operating pressure. See 841.5.

(b) Pipelines or mains located in Location Class 2 shall be tested either with air to 1.25 times the maximum operating pressure or hydrostatically to at least 1.25 times the maximum operating pressure. See 841.5.

(c) Pipelines and mains in Location Classes 3 and 4 shall be tested hydrostatically to a pressure not less than 1.4 times the maximum operating pressure.

(d) The test requirements given in 841.412(a), (b) and (c) above are summarized in Table 841.412 (d).

841.413 Requirements of 841.412 (c) for hydrostatic testing of mains and pipelines in Location Classes 3 and 4 do not apply if at the time the pipeline or main is first ready for test, one or both of the following conditions exist:

(a) The ground temperature at pipe depths is 32 F or less, or might fall to that temperature before the hydrostatic test could be completed, or

(b) Water of satisfactory quality is not available in sufficient quantity.

(c) In such cases an air test to 1.1 times the maximum operating pressure shall be made and the limitations on operating pressure imposed by 841.412(d) above do not apply.

841.414 Other provisions of this code notwithstanding, pipelines and mains crossing highways and railroads may be tested in each case in the same manner and to the same pressure as the pipeline on each side of the crossing.

841.415 Other provisions of this code notwithstanding, fabricated assemblies, including mainline valve assemblies, cross connections, river crossing headers, etc., installed in pipelines in Class 1 locations and designed in accordance with Type B construction, as required in 841.142, may be tested as required for Class 1 locations.

841.416 Nothwithstanding the limitations on air testing imposed in 841.412 (c), air testing may be used in Location Classes 3 and 4, provided that all of the following conditions apply:

(a) The maximum hoop stress during test is less than 50 percent of the specified minimum yield strength in Class 3 locations, and less than 40 percent of the specified minimum yield strength in Class 4 locations.

(b) The maximum pressure at which the pipeline or main is to be operated does not exceed 80 percent of the maximum field test pressure used.

(c) The pipe involved is new pipe having a longitudinal joint factor E in Table 841.12 of 1.00.

841.42 **Tests Required to Prove Strength for Pipelines and Mains to Operate at Less than 30 Percent of the Specified Minimum Yield Strength of the Pipe, but in Excess of 100 psi.** Steel piping that is to operate at stresses less than 30 percent of the specified minimum yield strength but in excess of 100 psi in location classes 2, 3 and 4 shall be tested to at least 1.5 times the maximum operating pressure. The test medium used may be water, air or gas; provided, however, that no medium shall be used to a higher hoop stress during the test than the maximums set in Table 841.421.

Leak Tests for Pipelines or Mains to Operate at 100 psi or More

841.431 Each pipeline and main shall be tested after construction and before being placed in operation to demonstrate that it does not leak. If the test indicates that a leak exists, the leak or leaks shall be located and eliminated, unless it can be determined that no undue hazard to public safety exists.

841.432 The test procedure used shall be capable of disclosing all leaks in the section being tested and shall be selected after giving due consideration to the volumetric content of the section and to its location.

841.433 In all cases where a line is to be stressed in a strength-proof test to 20 percent or more of the specified minimum yield strength of the pipe, and gas or air is the test medium, a leak test shall be made at a pressure in the range from 100 psi to that required to produce a hoop stress of 20 percent of the minimum specified yield, or the line shall be walked while the hoop stress is held at approximately 20 percent of the specified minimum yield.

Table 841.421
Maximum Hoop Stress Permissible During Test.

	Percent of Specified Minimum Yield Strength			
Location class	1	2	3	4
Test medium				
Water	No max.	No max.	No max.	No max.
Air	79.2	75	50	40
Gas	79.2	30	30	30

Leak Tests for Pipelines and Mains to Operate at Less Than 100 psi

841.441 At the time of or prior to placing in operation distribution mains and related equipment to operate at less than 100 psi, they shall be tested to determine that they are gas-tight.

841.442 Gas may be used as the test medium at the maximum pressure available in the distribution system at the time of the test. In this case the soap bubble test may be used to locate leaks if all joints are accessible during the test.

841.443 Testing at available distribution system pressures as provided for in 841.442 may not be adequate if substantial protective coatings are used that would seal a split pipe seam. If such coatings are used, the leak test pressure shall be 100 psi.

841.5 **Safety During Test.** All testing of pipelines and mains after construction shall be done with due regard for the safety of employees and the public during the test. When air or gas is used, suitable steps shall be taken to keep persons not working on the testing operations out of the testing area during the period in which the hoop stress is first raised from 50 percent of the specified minimum yield to the maximum test stress, and until the pressure is reduced to the maximum operating pressure.

CAST IRON

Cast Iron Pipe Design

842.11 **Basic Equation to Determine Required Wall Thickness.** Cast iron pipe shall be designed in accordance with the methods set forth in the ASA A21.1 "American Recommended Practice Manual for the Computation of Strength and Thickness of Cast Iron Pipe."

842.12 **Maximum Allowable Values of S and R.** The values of S, bursting tensile strength, and R, modulus of rupture, to be used in the equations given in ASA A21.1 are:

Specification	Type of Pipe	S Bursting Tensile Strength	R Modulus of Rupture
ASA A21.3	Pit Cast	11,000 psi	31,000 psi
ASA A21.7	Centrifugal (Metal Mold)	18,000 psi	40,000 psi
ASA A21.9	Centrifugal (Sand-lined Mold)	18,000 psi	40,000 psi

842.13 **Allowable Thicknesses for Cast Iron Pipe.** The least cast iron pipe thicknesses permitted are the lightest standard classes for each nominal pipe size as shown in ASA Specifications A21.3, A21.7 and A21.9.

842.14 **Standard Thickness for Cast Iron Pipe.** The wall thickness, diameter, and maximum working pressure permitted under ASA A21.1 for the type and sizes of cast iron pipe most commonly used for gas piping are shown in Tables 842.141 and 842.142. For pipe sizes, pressure, thicknesses, or laying conditions now shown in these tables, reference should be made to ASA A21.1 for the method of calculation.

Cast Iron Pipe Joints

842.15 (a) **Caulked Bell and Spigot Joints.** Dimensions for caulked bell and spigot joints shall conform to the American Standards Association Specifications A21.3, A21.7, A21.9 and A21.10. This type of joint shall not be used for pressures in excess of 25 psig, unless reinforced with mechanical clamps.

(b) **Mechanical Joints.** Mechanical joints shall utilize gaskets made of a resilient material as their sealing medium. The material selected for gaskets shall be of a type not adversely affected by the gas or condensates in the main. The gaskets shall be suitably confined and retained under compression by a separate gland or follower ring. A joint of this type is shown in ASA Specification A21.11.

(c) **Threaded Joints.** The use of threaded joints to couple lengths of cast iron pipe is not recommended.

(d) **Flanged Joints.** The dimensions and drilling for flanges shall conform to the ASA B-16 series of the American Standard for Cast Iron Pipe Flanges and Flanged Fittings. Flanges shall be cast integrally with fittings or valves.

(e) **Special Joints.** Special joints are not prohibited provided they are properly qualified and utilized in accordance with appropriate provisions of this code.

Installation of Cast Iron Pipe

842.21 Underground cast iron pipe shall be laid in accordance with the applicable field conditions described in the ASA "American Recommended Practice Manual" A21.1.

842.22 Underground cast iron pipe shall be installed with a minimum cover of 24 in. unless prevented by other underground structures.

842.23 Where sufficient cover cannot be provided to protect the pipe from external loads or damage and the pipe is not designed to withstand such external loads, the pipe shall be cased or bridged to protect the pipe.

842.24 Cast iron pipe installed in unstable soils shall be provided with suitable supports.

842.25 Suitable harnessing or buttressing shall be provided at points where the main deviates from a straight line and the thrust if not restrained would part the joints.

842.26 **Making and Testing of Cast Iron Field Joints.**

(a) Cast iron pipe joints shall conform to 842.15, and shall be assembled according to recognized AWWA, or ASA Specifications, or in accordance with the manufacturer's written recommendations.

(b) Cast iron pipe joints shall be leak tested in accordance with 841.44 of this code.

PIPE-TYPE AND BOTTLE-TYPE HOLDERS

844.1 **Pipe-Type Holders in Rights-of-Way Not Under Exclusive Use and Control of the Operating Company.** A pipe-type holder which is to be installed in streets, highways or in private rights-of-way not under the exclusive control and use of the operating company shall be designed, installed, and tested in accordance with the provisions of this code applicable to a pipeline installed in the same location and operated at the same maximum pressure.

844.2 **Bottle-type** holders shall be located on land owned or under the exclusive control and use of the operating company.

844.3 **Pipe-Type and Bottle-Type Holders on Property under the Exclusive Use and Control of the Operating Company.**

844.31 The storage site shall be entirely surrounded with fencing to prevent access by unauthorized persons.

844.32 (a) A pipe-type or bottle-type holder which is to be installed on property under the exclusive control and use of the operating company shall be designed in accordance with construction design factors the selection of which depends upon the location class in which the site is situated, the clearance between the pipe containers or bottles and the fence, and the maximum operating pressure, as follows:

Design Factors

Holder Site Location Class	Minimum Clearance between Containers and Fenced Boundaries of Site 25′ to 100′	Minimum Clearance between Containers and Fenced Boundaries of Site 100′ or Over
1	.72	.72
2	.60	.72
3	.60	.60
4	.40	.40

(b) The minimum clearance between containers and the fenced boundaries of the site is fixed by the maximum operating pressure of the holder as follows:

Maximum Operating Pressure	Minimum Clearance
Less than 1000 psi	25 ft
1000 psi or more	100 ft

(c) Minimum clearance between pipe containers or bottles. The minimum distance in inches between pipe containers or bottles shall be determined by the following formula:

$$C = \frac{3D \times P \times \text{"F"}}{1000}$$

in which:

C = Minimum clearance between pipe containers or bottles in inches.
D = Outside diameter of pipe container or bottle in inches.
P = Maximum allowable operating pressure in pounds per square inch gage.
"F" = Design Factor

(d) Pipe containers shall be installed underground with the top of each container not less than 24 in. below the ground surface.

(e) Bottles shall be installed underground with the top of each container below the normal frost line but in no case closer than 24 in. to the surface.

(f) Pipe-type holders shall be tested in accordance with the provisions of 841.41 for a pipeline located in the same location class as the holder site; provided, however, that in any case where the test pressure will produce a hoop stress of 80 percent or more of the specified minimum yield strength of the pipe, water shall be used as the test medium.

Special Provisions Applicable to Bottle-type Holders Only

844.41 A bottle-type holder may be manufactured from steel which is not weldable under field conditions, subject to all the following limitations.

(a) Bottle-type holders made from alloy steel shall meet the chemical and tensile requirements for the various grades of steel in API Standard 5A, "Specification for Casing, Tubing and Drill Pipe," or ASTM A372, "Specification for Carbon and Alloy Steels for Pressure Vessel Shells."

(b) In no case shall the ratio of actual yield strength to actual tensile strength exceed .85.

(c) Welding shall not be performed on such bottles after they have been heat treated and/or stress relieved, except that it shall be permissible to attach small copper wires to the small diameter portion of the bottle end closure for cathodic protection purposes using a localized thermit welding process.

(d) Such bottles shall be given a hydrostatic test in the mill, and need not be re-tested hydrostatically at the time of installation. The mill test pressure shall not be less than that required to produce a hoop stress equal to 85 percent of the specified minimum yield strength of the steel. Careful inspection of the bottles at the time of installation shall be made and no damaged bottle shall be used.

(e) Such bottles and connecting piping shall be tested for tightness after installation using air or gas at a pressure of 50 psi above the maximum operating pressure.

General Provisions Applicable to Both Pipe-type and Bottle-type Holders

(a) Suitable measures shall be taken to protect the storage system against external corrosion. (See 841.17)

(b) No gas containing more than 0.1 grain of hydrogen sulfide per 100 cu ft at 14.7 psia and 60 F shall be stored.

(c) Provision shall be made to prevent the formation or accumulation of liquids in the holder, connecting piping and auxiliary equipment, that might cause corrosion or might interfere with the safe operation of the storage equipment. Relief valves shall be installed in accordance with provisions of this code which will have relieving capacity adequate to limit the pressure imposed on the filling line and thereby on the storage holder to 110 percent of the design pressure of the holder, or to that pressure which produces a hoop stress of 75 percent of the specified minimum yield strength of the steel, whichever is the lesser.

CONTROL AND LIMITING OF GAS PRESSURE

845.1 **Basic Requirement for Protection Against Accidental Over-pressuring.** Every pipeline, main, distribution system, customer's meter and connected facilities, compressor station, pipe type holder, bottle type holder, container fabricated from pipe and fittings, and all special equipment, if connected to a compressor or to a gas source where the failure of pressure control or other causes might result in a pressure which would exceed the maximum allowable operating pressure of the facility (refer to 805.14), shall be equipped with suitable pressure relieving or pressure limiting devices. Special provisions for service regulators are set forth under paragraph 845.5.

845.2 **Control and Limiting of Gas Pressure in Holders, Pipelines, and All Facilities that Might at Times Be Bottle Tight.**

845.21 Suitable types of protective devices to prevent over-pressuring of such facilities are:

(a) Spring loaded relief valves of types meeting the provisions of the ASME Unfired Pressure Vessel Code.

(b) Pilot loaded back-pressure regulators used as relief valves, so designed that failure of the pilot system or control lines will cause the regulator to open.

845.22 **Maximum Allowable Operating Pressure for Pipelines or Mains.** This pressure is by definition the maximum operating pressure to which the pipeline or main may be subjected in accordance with the requirements of this code. For a pipeline or main in good operating condition, the maximum allowable operating pressure is the lesser of the two pressures described in (a) and (b) below.

(a) The design pressure (defined in 805.11) of the weakest element of the pipeline or main. Assuming that all fittings, valves and other accessories in the line have an adequate pressure rating, the maximum allowable operating pressure of a steel pipeline or main shall be the design pressure determined in accordance with 841.1.

(b) The pressure obtained by dividing the pressure to which the pipeline or main is tested after construction by the appropriate factor for the location class involved, as follows:

Location Class No.	Pressure
1	Test Pressure / 1.10
2	Test Pressure / 1.25
3	Test Pressure[1] / 1.40
4	Test Pressure[1] / 1.40

[1]Other factors than 1.4 should be used if the line was tested under the special conditions described in 841.413, 841.416 and 841.42. In such cases use factors that are consistent with the applicable requirements of these sections.

(c) In some cases the operating company will consider that the maximum operating pressure to which a pipeline or main should be subjected is less than the pressure determined by either (a) or (b) above. Pipelines that are known to be seriously corroded or that have other defects seriously affecting their strength and which have been operated for years at lower pressures, fall into this category. In such cases the operating company shall decide the maximum pressure it considers safe, and shall install over-pressure protective devices designed to prevent accidentally exceeding this maximum pressure, if there is a reasonable possibility that the pressure will be exceeded.

(d) If services are connected to the pipeline or main, there are additional considerations that might in some cases limit the maximum allowable operating pressure of the facility. See 845.33.

845.23 **Qualifying a Pipeline or Main for a New and Higher Maximum Allowable Operating Pressure.** *(Note: This paragraph applies to pipelines or mains where the new and higher maximum allowable operating pressure will produce a hoop stress of 30 percent or more of the specified minimum yield strength of the pipe. When the new and higher maximum allowable operating pressure is equal to or less than this value the provisions of 845.34 shall apply.)*

Before increasing the maximum allowable operating pressure of a pipeline or main that has been operating for a period of several years or more at a pressure less than that determined by 845.22(a) above, it is required that:

(a) The following investigative and corrective measures be taken:

(1) The design and previous testing of the pipeline and the materials and equipment in it be reviewed to determine that the proposed increase in allowable operating pressure is safe and in general agreement with the requirements of this code.

(2) The condition of the line be determined by field inspections, examination of maintenance records, or other suitable means.

(3) Repairs, replacements or alterations in the pipeline disclosed to be necessary by steps (1) and (2) be made.

(b) The maximum allowable operating pressure may be increased after compliance with (a) above and one of the following provisions:

(1) If the physical condition of the line as determined by (a) above indicates that the line is capable of withstanding the desired increased operating pressure in accordance with the design requirements of this code and the line has previously been tested to a pressure equal to or greater than that required by this code for a new line for the proposed new maximum allowable operating pressure, the line may be operated at the increased maximum allowable operating pressure.

(2) If the physical condition of the line as determined by (a) above indicates that the ability of the line to withstand the increased maximum operating pressure has not been satisfactorily verified or the line has not been previously tested to the levels required by this edition of the code for a new line for the proposed new maximum allowable operating pressure, the line may be operated at the increased maximum allowable operating pressure if the line shall successfully withstand the test required by this edition of the code for a new line to operate under the same conditions.

(3) If, under the foregoing provisions of (b) above, it is necessary to test a pipeline or main before it can be up-rated to a new maximum allowable operating pressure, and if it is not practical to test the line either because of the expense or difficulties created by taking it out of serv-

ice, or because of other operating conditions, a new and higher maximum allowable operating pressure may be established as follows:

3.1 Perform the requirements of (a) above.

3.2 Select a new maximum allowable operating pressure consistent with the condition of the line and the design requirements of this code; provided, however, that,

3.3 In no such case shall the new maximum allowable operating pressure exceed 80 percent of that permitted for a new line of the same design in the same location.

(c) In no case shall the maximum allowable operating pressure of a pipeline be raised to a value higher than would be permitted by this code for a new line constructed of the same materials and in the same locations.

The rate of pressure increase to the new maximum allowable pressure should be gradual so as to allow sufficient time for periodic observations of the pipeline.

Control and Limiting of Gas Pressure In High-Pressure Distribution Systems

845.31 Each high-pressure distribution system or main, supplied from a source of gas which is at a higher pressure than the maximum allowable operating pressure for the system, shall be equipped with pressure regulating devices of adequate capacity, and designed to meet the pressure, load and other service conditions under which they will operate or to which they may be subjected.

845.32 In addition to the pressure regulating devices prescribed in 845.31, a suitable method shall be provided to prevent accidental over-pressuring of a high-pressure distribution system.

Suitable types of protective devices to prevent overpressuring of high pressure distribution systems include:

(a) Relief valves as prescribed in 845.21 (a) and (b).

(b) Weight loaded relief valves

(c) A monitoring regulator installed in series with the primary pressure regulator.

(d) A series regulator installed upstream from the primary regulator, and set to continuously limit the pressure on the inlet of the primary regulator to the maximum allowable operating pressure of the distribution system or less.

(e) An automatic shut-off device installed in series with the primary pressure regulator, and set to shut off when the pressure on the distribution system reaches the maximum allowable operating pressure, or less. This device must remain closed until manually reset. It should not be used where it might cause an interruption in service to a large number of customers.

Maximum Allowable Operating Pressure For High-Pressure Distribution Systems

This pressure shall be the maximum pressure to which the system can be subjected in accordance with requirements of this code. It shall not exceed:

(a) The design pressure of the weakest element of the system as defined in 805.11.

(b) 60 psig if the services in the system are not equipped with series regulators or other pressure limiting devices as prescribed in 845.53.

(c) 25 psig in cast iron systems having unreinforced bell and spigot joints as prescribed in 842.15 (a).

(d) 2 psig in high-pressure distribution systems equipped with service regulators not meeting the requirements of 845.51 and which do not have an overpressure protective device as required in 845.52.

In some cases the operating company will consider the maximum pressure to which a system should be subjected is less than the pressure obtained by applying the applicable limits in 845.33 (a), (b), (c) or (d). Systems that are known to be corroded and that have been operated for years at lower pressures than these limits fall into this category. In such cases the operating company shall decide the maximum pressure it considers safe, and shall install over-pressure protective devices to prevent accidentally exceeding this maximum pressure if there is a reasonable possibility that the pressure will be exceeded.

845.34 **Qualifying a High-Pressure Distribution System for a New and Higher Maximum Allowable Operating Pressure.** Note: This paragraph applies to high-pressure distribution mains and to pipelines where the new and higher maximum allowable operating pressure is less than that required to produce a hoop stress of 30 percent of the specified minimum yield strength of the pipe. When the new and higher maximum allowable operating pressure is more than this value the provisions of 845.23 shall apply.

(a) Before increasing the maximum allowable operating pressure of a high-pressure distribution system, that has been operating at less than the applicable maximum pressure stated in 845.33, to a new maximum allowable operating pressure equal to or less than the maximum applicable pressure in 845.33, it is recommended that the following factors be taken in consideration:

(1) The design of the system including kinds of material and equipment used.

(2) Past maintenance records including results of any previous leakage surveys.

(b) Before increasing the pressure the following steps should be taken:

(1) Make a leakage survey, if past maintenance records indicate that such a survey is advisable, and repair leaks found.

(2) Repair or replace parts of the system found to be inadequate for the higher operating pressure.

(3) If the new maximum allowable operating pressure is to be over 60 psig, install suitable devices on the services to regulate and limit the pressure of the gas in accordance with 845.53.

(4) At bends or offsets in coupled or bell and spigot pipe, reinforce or replace anchorages determined to be inadequate for the higher operating pressure.

(c) The rate of pressure increase to the new maximum allowable operating pressure should be gradual so as to allow sufficient time for periodic observations of the system.

Control and Limiting of Gas Pressure In Low-Pressure Distribution Systems

845.41 Each low-pressure distribution system or low pressure main supplied from a gas source which is at a higher pressure than the maximum allowable operating pressure for the low-pressure system, shall be equipped with pressure regulating devices of adequate capacity, designed to meet the pressure, load and other service conditions under which they will have to operate.

845.42 In addition to the pressure regulating devices prescribed in 845.41, a suitable device shall be provided to prevent accidental overpressuring. Suitable types of protective devices to prevent overpressuring of low pressure distribution systems include:

(a) A liquid seal relief valve that can be set to open accurately and consistently at the desired pressure, and to close again when the pressure in the distribution system returns to normal.

(b) Weight loaded relief valves.

(c) An automatic shut-off device as described in 845.32 (e).

(d) A pilot loaded back-pressure regulator as described in 845.21 (b).

(e) A monitoring regulator as described in 845.32 (c).

(f) A series regulator as described in 845.32 (d).

845.43 **Maximum Allowable Operating Pressure for Low Pressure Distribution Systems.** The maximum allowable operating pressure for a low pressure distribution system shall not exceed either (a) or (b) below.

(a) A pressure which would cause the unsafe operation of any connected and properly adjusted low pressure gas burning equipment, or

(b) A pressure of 2 psig.

845.44 **Conversion of Low-Pressure Distribution Systems to High-Pressure Distribution Systems.**

(a) Before converting a low-pressure distribution system to a high-pressure system, it is recommended that the following factors be taken into consideration:

(1) The design of the system including kinds of material and equipment used.

(2) Past maintenance records including results of any previous leakage surveys.

(b) Before increasing the pressure the following steps (not necessarily in sequence shown) should be taken:

(1) Make a leakage survey, if past maintenance records indicate that such a survey is advisable, and repair leaks found.

(2) Reinforce or replace parts of the system found to be inadequate for the higher operating pressures.

(3) Install a service regulator on each service, and test each regulator to determine that it is functioning. In some cases it may be necessary to raise the pressure slightly to permit proper operation of the service regulator.

(4) Isolate the system from adjacent low-pressure systems.

(5) At bends or offsets in coupled or bell and spigot pipe, reinforce or replace anchorages determined to be inadequate for the higher pressures.

(c) The pressure in the system being converted should be increased by steps, with a period to check the effect of the previous increase before making the next increase. The desirable magnitude of each increase and the length of the check period will vary depending upon conditions. The objective of this procedure is to afford an opportunity to discover before excessive pressures are reached any unknown open and unregulated connections to adjacent low-pressure systems or to individual customers.

845.5 **Control and Limiting of the Pressure of Gas Delivered to Domestic, Small Commercial and Small Industrial Customers from High Pressure Distribution Systems.** *(Note: When the pressure of the gas and the demand by the customer are greater than that which is applicable under the provisions of 845.5, the requirements for control and limiting of the pressure of gas delivered are included in 845.1.)*

845.51 If the maximum actual operating pressure of the distribution system is between 2 psig and 60 psig and a service regulator having the characteristics listed below is used, no other pressure limiting device is required:

(a) A pressure regulator capable of reducing distribution line pressure (pounds per square inch) to pressures recommended for household appliances (inches of water column).

(b) Single port valve with orifice diameter no greater than that recommended by the manufacturer for the maximum gas pressure at the regulator inlet.

(c) The valve seat shall be made of resilient material designed to withstand abrasion of the gas, impurities in gas, cutting by the valve, and to resist permanent deformation when it is pressed against the valve port.

(d) Pipe connections to the regulator shall not exceed 2 in. in diameter.

(e) The regulator must be of a type that is capable under normal operating conditions of regulating the downstream pressure within the necessary limits of accuracy and of limiting the build-up of pressure under no-flow conditions to 50 percent or less of the discharge pressure maintained under flow conditions.

(f) A self-contained service regulator with no external static or control lines.

845.52 If the maximum actual operating pressure of the distribution system is between 2 psig and 60 psig and a service regulator not having all of the characteristics listed in 845.51 is used, or if the gas contains materials that seriously interfere with the operation of service regulators, suitable protective devices shall be installed to prevent accidental overpressuring of the customer's appliances should the service regulator fail. Some of the suitable types of protective devices to prevent overpressuring of customer's appliances are:

(a) A monitoring regulator

(b) A relief valve

(c) An automatic shut-off device

These devices may be installed as an integral part of the service regulator or as a separate unit.

845.53 If the maximum actual operating pressure of the distribution system exceeds 60 psig, suitable methods shall be used to regulate and limit to the maximum safe value, the pressure of the gas delivered to the customer, such as the following:

(a) A service regulator having the characteristics listed in 845.51 above and a secondary regulator located upstream from the service regulator. The secondary regulator in no case shall be set to maintain a pressure higher than 60 psi. A device shall be installed between the secondary regulator and the service regulator to limit the pressure on the inlet of the service regulator to 60 psi or less in case the secondary regulator fails to function properly. This device may be either a relief valve, or an automatic shut-off that shuts, if the pressure on the inlet of the service regulator exceeds the set pressure (60 psi or less), and remains closed until manually reset.

(b) A service regulator and a monitoring regulator set to limit to a maximum safe value the pressure of the gas delivered to the customer.

(c) A service regulator with a relief valve vented to the outside atmosphere, with the relief valve set to open so that the pressure of the gas going to the customer shall not exceed a maximum safe value. The relief valve may either be built into the service regulator or it may be a separate unit installed downstream from the service regulator. This combination may be used alone only in those cases where the inlet pressure on the service regulator does not exceed the manufacturer's safe working pressure rating of the service regulator, and is not recommended for use where the inlet pressure on the service regulator exceeds 125 psi. For higher inlet pressures, method (a) or (b) above should be used.

Requirements for Design of All Pressure Relief and Pressure Limiting Installations

845.61 All pressure relief or pressure limiting devices shall:

(a) Be constructed of materials such that the operation of the device will not normally be impaired by corrosion of external parts by the atmosphere, or of the internal parts by gas.

(b) Have valves and valve seats that are designed not to stick in a position that will make the device inoperative and result in failure of the device to perform in the manner for which it was intended.

(c) Be designed and installed so that they can be readily operated to determine if the valve is free; and can be tested to determine the pressure at which they will operate; and can be tested for leakage when in the closed position.

845.62 The discharge stacks, vents, or outlet ports of all pressure relief devices shall be located where gas can be discharged into the atmosphere without undue hazard. Consideration shall be given to all exposures in the immediate vicinity. Where required to protect devices, the discharge stacks, or vents, shall be protected with rain caps to preclude the entry of water.

845.63 The size of the openings, pipe and fittings located between the system to be protected and the pressure relieving device, and the vent line, shall be of adequate size to prevent hammering of the valve and to prevent impairment of relief capacity.

845.64 Precautions shall be taken to prevent unauthorized operation of any stop valve which will make a pressure relief valve inoperative. This provision shall not apply to valves, the operation of which will isolate the system under protection from its source of pressure. Acceptable methods for complying with this provision are:

(a) Lock the stop valve in the open position. Instruct authorized personnel of the importance of not inadvertently leaving the stop valve closed and of being present during the entire period that the stop valve is closed so that they can lock it in the open position before they leave the location.

(b) Install duplicate relief valves, each having adequate capacity by itself to protect the system, and arrange the isolating valves or 3-way valve so that mechanically it is possible to render only one safety device inoperative at a time.

845.65 Precautions shall be taken to prevent unauthorized operation of any valve which will make pressure limiting devices inoperative. This provision applies to isolating valves, by-pass valves, and valves on control or float lines which are located between the pressure limiting device and the system which the device protects. A method similar to 845.64 (a) shall be considered acceptable in complying with this provision.

845.66 (a) When a monitoring regulator, series regulator, system relief or system shut-off, is installed at a district regulator station to protect a piping system from overpressuring, the installation shall be designed and installed to prevent any

single incident such as an explosion in a vault or damage by a vehicle from affecting the operation of both the overpressure protective device and the district regulator.

(b) Special attention shall be given to control lines. All control lines shall be protected from falling objects, excavations by others, or other foreseeable causes of damage and shall be designed and installed to prevent damage to any one control line from making both the district regulator and the overpressure protective device inoperative.

Required Capacity of Pressure Relieving and Pressure Relief Devices

845.71 Each pressure relief station or pressure limiting station or group of such stations installed to protect a piping system or pressure vessel shall have sufficient capacity and shall be set to operate to prevent the pressure from exceeding the maximum allowable operating pressure, plus 10 percent, or the pressure which produces a hoop stress of 75 percent of the specified minimum yield strength, whichever is lower, or in a low pressure distribution system, a pressure which would cause the unsafe operation of any connected and properly adjusted gas burning equipment.

845.72 When more than one pressure regulating or compressor station feeds into a pipeline or distribution system and pressure relief devices are installed at such stations, the relieving capacity at the remote stations may be taken into account in sizing the relief devices at each station. However, in doing this the assumed remote relieving capacity must be limited to the capacity of the piping system to transmit gas to the remote location or to the capacity of the remote relief device, whichever is less.

Proof of Adequate Capacity and Satisfactory Performance of Pressure Limiting and Pressure Relief Devices

845.81 Where the safety device consists of an additional regulator which is associated with or functions in combination with one or more regulators in a series arrangement to control or limit the pressure in a piping system, suitable checks shall be made to determine that the equipment will operate in a satisfactory manner to prevent any pressure in excess of the established maximum allowable operating pressure of the system should any one of the associated regulators malfunction or remain in the wide open position.

845.82 Suitable checks shall be made periodically to insure that the combined capacity of the relief devices on a piping system or facility is adequate to limit the gas pressure at all times to values prescribed by this code. This check should be based on the operating conditions that create the maximum probable requirement for relief capacity in each case, even though such operating conditions actually occur infrequently and/or for only short periods of time.

CUSTOMERS' METERS AND REGULATORS

Location for Customers' Meter and Regulator Installations

846.1 (a) Customers' meters and regulators may be located either inside or outside of buildings, depending upon local conditions, except, that on services requiring series regulation, in accordance with 845.53 (a), the upstream regulator shall be located outside of the building.

(b) When installed within a building, the service regulator shall be in a readily accessible location near the point of gas service entrance and, whenever practical, the meters shall be installed at the same location. Meters shall not be installed in bedrooms, closets, bathrooms, under combustible stairways or in unventilated or inaccessible places, nor closer than three feet to sources of ignition, including furnaces and water heaters. On services supplying large industrial customers or installations where gas is utilized at higher than standard service pressure, the regulators may be installed at other readily accessible locations.

(c) When located outside of buildings, meters and service regulators shall be installed in readily accessible locations where they will be reasonably protected from damage.

(d) Regulators requiring vents for their proper and effective operation shall be vented to the outside atmosphere in accordance with the provisions of 846.33.

846.2 **Operating Pressures for Customers' Meter Installations.** Iron or aluminum case meters shall not be used at a maximum operating pressure higher than the manufacturer's rating for the meter. New tinned steel case meters shall not be used at a pressure in excess of 50 percent of the manufacturer's test pressure; rebuilt tinned steel case meters shall not be used at a pressure in excess of 50 percent of the pressure used to test the meter after rebuilding.

Protection of Customers' Meters and Regulator Installations from Damage

846.31 Meters and service regulators shall not be installed where rapid deterioration from corrosion or other causes is likely to occur.

846.32 A suitable protective device such as a backpressure regulator, or a check valve, shall be installed downstream of the meter if and as required under the following conditions:

(a) If the nature of the utilization equipment is such that it may induce a vacuum at the meter, install a back-pressure regulator downstream from the meter.

(b) Install a check valve or equivalent if:

The utilization equipment might induce a back-pressure.

The gas utilization equipment is connected to a source of oxygen or compressed air.

Liquefied petroleum gas or other supplementary gas is used as standby and might flow back into the meter. A three-way valve installed to admit the standby supply and at the same time shut off the regular supply, can be substituted for a check valve if desired.

846.33 All service regulator vents, and relief vents where required, shall terminate in the outside air in rain and insect resistant fittings. The open end of the vent shall be located where, if a regulator failure resulting in the release of gas occurs, the gas can escape freely into the atmosphere and away from any openings into the buildings. At locations where service regulators might be submerged during floods, either a special anti-flood type breather vent fitting shall be installed, or the vent line shall be extended above the height of the expected flood waters.

846.34 Pits and vaults, housing customers' meters and regulators, shall be designed to support vehicular traffic when installed at the following locations:

(a) Travelled portions of alleys, streets and highways.

(b) Driveways.

846.4 **Installation of Meters and Regulators.** All meters and regulators shall be installed in such a manner as to prevent undue stresses upon the connecting piping and/or the meter. Lead connections or other connections made of material which can be easily damaged, shall not be used. The use of standard weight close nipples is prohibited.

GAS SERVICES

General Provisions Applicable to Both Steel and Copper Services

847.11 **Installation of Services.**

(a) Services shall be installed at a depth which will protect them from excessive external loadings, and local activities, such as gardening. It is recommended that a minimum depth of 12 in. in private property and a minimum depth of 18 in. in streets and roads be maintained. Where this cannot be done, due to existing substructures, etc., less cover is permitted provided, however, that where such services are subject to excessive superimposed loads, those portions of the service shall be cased or bridged to avoid harmful additional loads on the pipe, or strengthened to resist them.

(b) Service piping shall be properly supported at all points on undisturbed or well compacted soil, so that the pipe will not be subject to excessive external loading by the backfill. The material used for the backfill shall be free of rocks, building materials, etc., that might cause damage to the pipe or the protective coating.

(c) Where there is evidence of condensate in the gas in sufficient quantities to cause interruptions in the gas supply to the customer, the service shall be graded so as to drain in the main or to drip at the low points in the service.

847.12 **Types of Valves Suitable for Service Shut-offs.**

(a) Valves or cocks used as service shut-offs shall meet the applicable requirements of 810 and 831.11.

(b) The use of soft seat shut-off valves or cocks is not recommended.

(c) A valve incorporated in a meter bar which permits the meter to be by-passed does not qualify under this code as a service shut-off.

(d) Service shut-offs on high pressure services, installed either inside of buildings or in confined locations outside of buildings where the blowing of gas would be hazardous, shall be designed and constructed to minimize the possibility of the removal of the core of the valve or cock accidentally or willfully with ordinary household tools.

(e) The operating company shall make certain that the shut-off valves or cocks installed on high pressure services are suitable for this use either by making their own tests or by reviewing the tests made by the manufacturers.

(f) On services designed to operate at pressures in excess of 60 psig the service shut-off valve or cock shall be the equivalent of a pressure lubricated cock or a needle type valve. Other types of valves or cocks may be used where tests by the manufacturer or by the user indicate that they are suitable for this kind of service.

847.13 **Location of Service Shut-Offs.**

(a) Service shut-offs shall be installed on all new services (including replacements) in a readily accessible location.

(b) Shut-offs shall be located upstream of the meter if there is no regulator, or upstream of the regulator, if there is one.

(c) All gas services operating at a pressure greater than 10 psig, and all services 2 in. in diameter or larger, shall be equipped with a shut-off located on the service line outside of the building, except that whenever gas is supplied to a theatre, church, school, factory or other building where large numbers of persons assemble, an outside shut-off in such case will be required regardless of the size of the service or of the service pressure.

(d) Underground shut-offs shall be located in a covered durable curb box or standpipe, which is designed to permit ready operation of the valve. The curb box or standpipe shall be supported independently of the gas service line.

847.14 **Location of Service Connections to Main Piping.** It is recommended that services be connected to either the top or the side of the main. The connection to the top of the main is preferred, in order to minimize the possibility of dust and moisture being carried from the main into the service.

847.15 **Testing of Services After Construction.** Each service shall be tested after construction and before being placed in service to demonstrate that it does not leak.

Services to operate at a pressure between 1 psig and 40 psig, shall be given a stand-up air or gas pressure test at not less than 50 psig for at least five minutes before being placed in service.

Services to operate at pressures in excess of 40 psig, but stressed less than 20 percent of the specified minimum yield, shall be tested to the maximum operating pressure or 100 psig, whichever is the lesser. Services stressed to 20 percent or more of the specified minimum yield shall be tested in accordance with the requirements for mains.

The service connection to the main need not be included in these pressure tests if it is not feasible to do so.

Steel Services

847.21 **Design of Steel Services.**

(a) Steel pipe, when used for gas services, shall conform to the applicable requirements of Chapter I.

(b) Underground steel services, when installed below grade through the outer foundation wall of a building, shall be either encased in a sleeve or otherwise protected against corrosion. The service pipe and/or sleeve shall be sealed at the foundation wall to prevent entry of gas or water.

(c) Steel services, where installed underground under buildings, shall be encased in a gas tight conduit. When such a service supplies the building it subtends, the conduit shall extend into a normally usable and accessible portion of the building and, at the point where the conduit terminates, the space between the conduit and the service pipe shall be sealed to prevent the possible entrance of any gas leakage.

(d) Where practical, welded joints or compression type fittings should be used in all underground steel services.

(e) Consideration shall be given to insulating, near or within the building, those services which are connected through the house piping to water services, electrical ground, etc., so as to eliminate possible galvanic corrosion. This is especially important in areas where stray current electrolysis is prevalent, or where copper or lead water services are used.

847.22 **Installation of Steel Services in Bores.** When coated steel pipe is to be installed as a service pipe in a bore, care should be exercised to prevent damage to the coating during installation. For all installations to be made by boring, driving or similar methods or in a rocky type soil, the following practices or their equivalents are recommended:

(a) When a service is to be installed by boring or driving and a coated steel pipe is to be used for the service, the coated pipe should not be used as the bore pipe or drive pipe and left in the ground as part of the service. It is preferable to make such installations by first making an oversize bore, removing the pipe used for boring and then inserting the coated pipe.

(b) Coated steel pipe preferably should not be inserted through a bore in exceptionally rocky soil where there is a likelihood of damage to the coating resulting from the insertion.

847.23 The recommendations in (a) and (b) above do not apply when bare steel pipe is used as the service pipe, or where coated pipe is installed under conditions where the coating is not likely to be damaged, such as in sandy soil.

847.24 **Service Connections to Steel Mains.**

Services may be connected to steel mains by:

(a) Welding a service tee or similar device to the main.

(b) Using a service clamp or saddle.

(c) Compression fittings using rubber or rubber-like gaskets or welded connections may be used to connect service pipe to the main connection fitting. Gaskets used in a manufactured gas system shall be of a type that resists effectively that type of gas.

Cast Iron Services

847.31 **Use of Cast Iron Services.** When used for gas services, cast iron pipe shall meet the applicable requirements of 842. The use of cast iron pipe less than 6 in. in diameter for gas services is prohibited. Cast iron pipe 6 in. or larger in diameter, may be used for gas services except for that portion of the service which extends through the building wall. The latter portion shall be of steel pipe. Cast iron services shall not be installed in unstable soils or under buildings.

847.32 **Service Connections to Cast Iron Mains.** Services may be connected to cast iron mains by:

(a) Drilling and tapping the main; provided, however, that the diameter of the tapped hole shall not exceed the limitations imposed by 831.33 (b).

(b) Using a reinforcing sleeve.

847.321 Service connections shall not be brazed directly to cast iron mains.

847.322 Compression fittings using rubber or rubber-like gaskets or welded connections may be used to connect the service pipe to the main connection fitting. Gaskets used in a manufactured gas system shall be of a type that resists effectively that type of gas.

Copper Services (and Mains)

847.41 **Copper Pipe Design Requirements.** The following requirements shall apply to copper pipe, or tubing, when used for gas mains or services:

(a) Copper pipe, or tubing, shall not be used for services or mains where the pressure exceeds 100 psig.

(b) Copper pipe, or tubing, shall not be used for services or mains where the gas carried contains more than an average of 0.3 grains of hydrogen sulfide per 100 standard cubic feet of gas. This is equivalent to a trace as determined by the lead-acetate test.

(c) Copper pipe, or tubing, shall not be used for services or mains where the piping strain or external loading may be excessive.

(d) Copper services may be installed within buildings, provided that the service is not concealed and is suitably protected against external damage.

(e) Copper tubing, or pipe for mains, shall have a minimum wall thickness of 0.065 in. and shall be hard drawn.

(f) The minimum wall thickness for copper pipe, or tubing used for gas services, shall be not less than Type "L" as specified in ASTM specifications for Copper Water Tube, designation B-88.

(g) Underground copper services, installed through the outer foundation wall of a building, shall be either encased in a sleeve, or otherwise protected against corrosion. The service pipe, or tubing, and/or sleeve shall be sealed at the foundation wall to prevent entry of gas or water.

(h) A copper service, installed underground under buildings, shall be encased in a conduit designed to prevent gas leaking from the service and getting into the building. Where joints are used, they shall be of the brazed or soldered type in accordance with 847.44.

847.42 **Valves in Copper Lines.** Valves installed in copper lines may be made of any suitable material permitted by this code, except that, ferrous valves installed on underground copper services shall be protected from contact with the soil and/or insulated from the copper pipe.

847.43 **Fittings in Copper Lines.** It is recommended that fittings in a copper line and exposed to the soil, such as service tees, pressure control fittings, etc., be made of bronze, copper or brass. If iron or steel fittings are used, they shall be protected as specified above for valves.

847.44 **Joints in Copper Pipe and Tubing.** Copper pipe shall be joined by using either a compression type coupling or a brazed or soldered lap joint. The filler material used for brazing shall be a copper-phosphorous alloy or silver base alloy. Butt welds are not permissible for joining copper pipe or tubing. Copper tubing shall not be threaded but copper pipe with wall thickness equivalent to the comparable size of Schedule 40 steel pipe may be threaded and used for connecting screw fittings or valves.

847.45 **Protection Against Galvanic Action Caused by Copper.** Provision shall be made to prevent harmful galvanic action where copper is connected underground to steel. This can be accomplished in most cases by using one or the other of the following methods:

(a) Install an insulating type coupling, or an insulating flange, between the copper and the steel, or

(b) Protect the copper and steel for a distance of two feet or more in all directions from the junction with insulating pipe corrosion protection material.

847.46 **Service Connections to Copper Mains.**

(a) Connections using a copper or cast bronze service tee or extension fitting sweat-brazed to the copper main, are recommended for copper mains.

(b) Butt welds are not permitted.

(c) Fillet-brazed joints are not recommended.

(d) The requirements of 847.44 shall apply to:

(1) Joints not specifically mentioned above, and

(2) All brazing material.

VALVES

Required Spacing of Valves

848.12 Valves on distribution mains, whether for operating or emergency purposes, shall be spaced as follows:

(a) **High Pressure Distribution Systems.** Valves shall be installed in high pressure distribution systems in accessible locations in order to reduce the time to shut down a section of main in an emergency. In determining the spacing of the valves consideration should be given to the operating pressure and size of the mains and local physical conditions as well as the number and type of consumers that might be affected by a shutdown.

(b) **Low Pressure Distribution Systems.** Valves may be used on low pressure distribution systems, but are not required except as specified in 848.22 (a).

Location of Valves

848.22 **Distribution System Valves.**

(a) A valve shall be installed on the inlet piping of each regulator station controlling the flow or pressure of gas in a distribution system. The distance between the valve and the regulator or regulators shall be sufficient to permit the operation of the valve during an emergency, such as a large gas leak or a fire in the station.

(b) Valves on distribution mains, whether for operating or emergency purposes, shall be located in a manner that will provide ready access and facilitate their operation during an emergency. Where a valve is installed in a buried box or enclosure, only ready access to the operating stem or mechanism is implied. The box or enclosure shall be installed in a manner to avoid transmitting external loads to the main.

VAULTS

849.1 **Structural Design Requirements.**

Underground vaults or pits for valves, pressure relieving, pressure limiting or pressure regulating stations, etc., shall be designed and constructed in accordance with the following provisions:

(a) All vaults and pits shall be designed and constructed in accordance with good structural engineering practice to meet the loads which may be imposed upon them.

(b) Sufficient working space shall be provided so that all of the equipment required in the vault can be properly installed, operated and maintained.

(c) In the design of vaults and pits for pressure limiting, pressure relieving and pressure regulating equipment, consideration shall be given to the protection of the equipment installed from damage, such as that resulting from an explosion within the vault or pit, which may cause portions of the roof or cover to fall into the vault.

(d) Piping entering, and within, regulator vaults or pits shall be steel for sizes 10 in. and less except that control and gage piping may be copper. Where piping extends through the vault or pit structure, provision shall be made to prevent the passage of gases or liquids through the opening and to avert strains in the piping. Equipment and piping shall be suitably sustained by metal, masonry, or concrete supports. The control piping shall be placed and supported in the vault or pit so that its exposure to injury or damage is reduced to a minimum.

(e) Vault or pit openings shall be located so as to minimize the hazards of tools or other objects falling upon the regulator, piping, or other equipment. The control piping and the operating parts of the equipment installed shall not be located under a vault or pit opening where workmen can step on them when entering or leaving the vault or pit, unless such parts are suitably protected.

(f) Whenever a vault or pit opening is to be located above equipment which could be damaged by a falling cover, a circular cover should be installed or other suitable precautions taken.

849.2 **Accessibility.** Consideration shall be given, in selecting a site for a vault, to its accessibility. Some of the important factors to consider in selecting the location of a vault are as follows:

(a) **Exposure to traffic.** The location of vaults in street intersections or at points where traffic is heavy or dense should be avoided.

(b) **Exposure to flooding.** Vaults should not be located at points of minimum elevation, near catch basins, or where the access cover will be in the course of surface waters.

(c) **Exposure to adjacent subsurface hazards.** Vaults should be located as far as is practical from water, electric, steam, or other facilities.

849.3 **Vault Ventilation.** Underground vaults and closed top pits composing either a pressure regulating or reducing station, or a pressure limiting or relieving station, shall be ventilated as follows:

(a) When the internal volume exceeds 200 cu ft, such vaults or pits shall be ventilated with two ducts each having at least the ventilating effect of a pipe 4 in. in diameter.

(b) The ventilation provided shall be sufficient to minimize the possible formation of a combustible atmosphere in the vault or pit.

(c) The ducts shall extend to a height above grade adequate to disperse any gas-air mixtures that might be discharged. The outside end of the ducts shall be equipped with a suitable weatherproof fitting or vent-head designed to prevent foreign matter from entering or obstructing the duct. The effective area of the openings in such fittings or vent-heads shall be at least equal to the cross-sectional area of a 4-in. duct. The horizontal section of the ducts shall be as short as practical and shall be pitched to prevent the accumulation of liquids in the line. The number of bends and offsets shall be reduced to a minimum and provisions shall be incorporated to facilitate the periodic cleaning of the ducts.

(d) Such vaults or pits having an internal volume between 75 and 200 cu ft may be either tightly closed or ventilated. If not ventilated, all openings shall be equipped with tight fitting covers without open holes through which an explosive mixture might be ignited. Means shall be provided for testing the internal atmosphere before removing the cover.

(e) If vaults or pits referred to in (d) above are ventilated by means of openings in the covers or gratings and the ratio of the internal volume, in cu ft, to the effective ventilating area of the cover or grating, in sq ft, is less than 20 to 1, no additional ventilation is required.

(f) Such vaults or pits having an internal volume less than 75 cu ft may be ventilated or not at the option of the operating company.

849.4 **Drainage and Waterproofing.**

(a) Provisions shall be made to minimize the entrance of water into vaults, and vault equipment shall always be designed to operate safely, if submerged.

(b) No vault containing gas piping shall be connected by means of a drain connection to any other substructure, such as a sewer.

(c) Electrical equipment in vaults shall conform to the requirements of Class 1, Group D, of the National Electrical Code (ASA CI).

Operating and Maintenance Procedures

850.1 Because of many variables, it is not possible to prescribe in a national code a set of operating and maintenance procedures that will be adequate from the standpoint of public safety in all cases without being burdensome and impractical in some.

850.2 It is possible, however, for each operating company to develop operating and maintenance procedures based on experience, knowledge of its facilities and conditions under which they are operated, which will be entirely adequate from the standpoint of public safety.

850.3 **Basic Requirement.** Each operating company having gas transmission or distribution facilities within the scope of this code shall:

(a) Have a plan covering operating and maintenance procedures in accordance with the purpose of this code.

(b) Operate and maintain its facilities in conformance with this plan.

(c) Keep records necessary to administer the plan properly.

(d) Modify the plan from time to time as experience with it dictates and as exposure of the public to the facilities and changes in operating conditions require.

850.4 **Essential Features of the Plan.** The plan prescribed in 850.3 (a) should include:

(a) Detailed plans and instructions to employees covering operating and maintenance procedures for gas facilities during normal operations and repairs, and during emergencies.

(b) Items recommended for inclusion in the plan for specific classes of facilities are given in 851 to 857, inclusive.

(c) Particular attention should be given to those portions of the facilities presenting the greatest hazard to the public in the event of an emergency or because of construction or extraordinary maintenance requirements.

Distribution Piping Maintenance

852.1 **Patrolling.** Distribution mains, which are installed in locations or on structures where abnormal physical movement or abnormal external loading could cause failure or leakage, shall be patrolled periodically and the frequency of the patrolling shall be determined by the severity of the conditions which could cause failure or leakage and the consequent hazards to public safety.

852.2 **Leakage Surveys and Routine Procedures**

852.21 Each operating company having a gas distribution system shall set up in its operating and maintenance plan a provision for the making of periodic leakage surveys. The types of surveys prescribed in the plan shall be one or more of the following employed singly or in combination, or some other effective procedure for locating leaks in the underground piping systems.

(a) Gas detector surveys.
(b) Bar test surveys.
(c) Vegetation surveys.
(d) Pressure drop surveys.
(e) Soapsuds testing on exposed pipe and fittings.

852.22 The nature of the operations and local conditions of each individual company shall determine the type and scope of the leakage control program most suitable. The character of the general service area together with housing concentration should determine the frequency of the inspection program.

It is recommended that the inspection program should include at least the following provisions:

(a) At least once a year a gas detector survey should be conducted in business districts, involving tests of the atmosphere in gas, electric, telephone, sewer and water system manholes, at cracks in pavement and sidewalks and at other locations providing an opportunity for finding gas leaks. Leakage surveys, using one or more of the types referred to in 852.21, should be made of the distribution system outside of the principal business areas as frequently as experience indicates that they are necessary but not less than once every five years.

(b) Leaks located by these surveys shall be investigated promptly and any necessary repairs shall be made. When the condition of a main or a service, as indicated by leak frequency records or visual observation, deteriorates to the point where it should not be retained in service, it should be replaced or reconditioned.

852.3 **Abandoning of Distribution Facilities.**

Each operating company shall have a plan in its operating and maintenance procedures for sealing off the supply of gas to all abandoned distribution facilities including services, mains, control lines, equipment and appurtenances. This plan shall include procedures for abandoning services that have remained inactive for a period of years and for which there is no planned use. It is recommended that the plan include the following provisions:

(a) If the facilities are abandoned in place and are disconnected or separated, the ends shall be capped, plugged or otherwise effectively sealed.

(b) In cases where a main is abandoned, together with the services connected to it, only the customer's end of such services need be sealed as stipulated above.

Procedures for Maintaining Pipe-Type and Bottle-Type Holders in Safe Operating Condition

854.1 Each operating company having a pipe-type or bottle-type holder shall prepare and place in its files a plan for the systematic, routine inspection and testing of the facilities which provides that:

854.11 Procedures shall be followed to enable the detection of external corrosion before the strength of the container has been impaired.

854.12 Periodic sampling and testing of gas in storage will be made to determine the dew point of vapors contained in the stored gas that might cause internal corrosion or interfere with the safe operations of the storage plant.

854.13 The pressure control and pressure limiting equipment will be inspected and tested periodically to see if it is in a safe operating condition and has adequate capacity.

854.2 Each operating company, having prepared such a plan as described in 854.1 above, shall follow the plan, and keep records which detail the inspection and testing work done and the conditions found.

854.3 All unsatisfactory conditions found shall be promptly corrected.

Maintenance of Pressure Limiting and Pressure Regulating Stations

855.1 All pressure limiting stations, relief devices, and pressure regulating stations and equipment shall be subjected to systematic periodic inspections and/or tests to determine that they are:

(a) In good mechanical condition.

(b) Adequate from the standpoint of capacity and reliability of operation for the service in which they are employed.

(c) Set to function at the correct pressure.

(d) Properly installed and protected from dirt, liquids, or other conditions that might prevent proper operation.

855.2 (a) Every distribution system supplied by more than one district pressure regulating station shall be equipped with telemetering or recording pressure gages to indicate the gas pressure in the district.

(b) On distribution systems supplied by a single district pressure regulating station the operating company shall determine the necessity of installing such gages in the district. In making this determination the operating company shall take into consideration the operating conditions such as the number of customers supplied, the operating pressures, and the capacity of the installation, etc.

(c) If there are indications of abnormal high or low pressure the regulator and the auxiliary equipment shall be inspected and the necessary measures shall be employed to rectify any unsatisfactory operating conditions. Suitable periodic inspections of single district pressure regulation stations not equipped with telemetering or recording gages shall be made to determine that the pressure regulating equipment is functioning properly.

855.3 Whenever it is practicable to do so, pressure relief valves should be tested in place to determine that they have sufficient capacity to limit the pressure on the facilities to which they are connected to the desired maximum pressure. If such tests are not feasible, periodic review and calculation of the required capacity of the relieving equipment at each station should be made and these required capacities compared with the rated or experimentally determined relieving capacity of the installed equipment for the operating conditions under which it works. If it is determined that the relieving equipment is of insufficient capacity, steps shall be taken to install new or additional equipment to provide capacity.

Valve Maintenance

856.1 **Pipeline Valves** that might be required during an emergency shall be inspected periodically and partially operated at least once per year to provide safe and proper operating conditions.

856.2 **Distribution System Valves.** Valves, the use of which may be necessary for the safe operation of a gas distribution system, shall be checked and serviced, including lubrication where necessary, at sufficiently frequent intervals to be reasonably assured of their satisfactory operation. Inspection shall include checking of alignment to permit use of a key or wrench and clearing from the valve box or vault any debris which would interfere with or delay the operation of the valve.

857 **Vault Maintenance.** Regularly scheduled inspections shall be made of each vault housing pressure regulating and pressure limiting equipment and having a volumetric internal content of 200 cu ft or more to determine if it is in good physical condition and adequately vented. This inspection shall include the testing of the atmosphere in the vault for combustible gas. If gas is found in the vault atmosphere, the equipment in the vault shall be inspected for leaks and leaks found shall be repaired. The ventilating equipment shall also be inspected to determine if it is functioning properly. If the ventilating ducts are obstructed, they shall be cleared. The condition of the vault covers shall be carefully examined to see that they do not present a hazard to public safety.

Miscellaneous

Odorization

861 Any gas, distributed to customers through gas mains or gas services or used for domestic purposes in compressor plants, which does not naturally possess a distinctive odor to the extent that its presence in the atmosphere is readily detectable at all gas concentrations of one-fifth of the lower explosive limit and above, shall have an odorant added to it to make it so detectable. Odorization is not necessary, however, for such gas as is delivered for further processing or use where the odorant would serve no useful purpose as a warning agent.

Liquefied Petroleum Gas (LPG) Systems

862.1 Liquefied petroleum gases, generally, include butane and propane, and mixtures of them that can be stored as liquids under moderate pressures (approximately 80 psig to 250 psig) at ambient temperatures.

862.2 This code is concerned only with certain safety aspects of liquefied petroleum gases when they are vaporized and used as gaseous fuels.

862.3 All of the requirements of Standards No. 58 and No. 59 of the National Board of Fire Underwriters and the National Fire Protection Association and of this code, concerning design, construction, and operation and maintenance of piping facilities shall apply to piping systems handling butane, propane, or mixture of these gases.

Special Safety Requirements for LPG Systems

862.41 **Odorization.** Liquefied petroleum gases are usually nontoxic, but for safety when distributed for consumer use, or used as fuel in a place of employment, they shall be odorized. Criteria for odorization are given in 861.

862.42 **Ventilation.**

(a) All liquefied petroleum gases are heavier than air, hence structures above ground for housing regulators, meters, etc., shall have open vents near the floor level. Such equipment shall not be installed in pits or in underground vaults, except in cases where suitable provisions for forced ventilation are made.

(b) Special care is required in the location of relief valve discharge vents releasing LPG to the atmosphere, to prevent accumulation of the heavy gases at or below ground level. Likewise, special precautions are necessary for adequate ventilation where excavations are made for the repair of leaks in an underground LPG distribution system.

Note: Refer to National Board of Fire Underwriters and the National Fire Protection Association Bulletins No. 58—Storage and Handling of Liquefied Petroleum Gases and No. 59—Liquefied Petroleum Gases at Utility Gas Plants.

Pipelines on Private Right-of-Way of Electric Transmission Lines

863 Where gas pipelines parallel overhead electric transmission lines on the same right of way, the company operating the pipelines shall take the following precautions:

863.1 Employ blow-out connections that will direct the gas away from the electric conductors.

863.2 Install a bonding conductor across points where the main is to be separated and maintain this connection while the pipeline is separated. The current carrying capacity of the bonding conductor should be at least one-half of the capacity of the overhead line conductors.

863.3 Make a study in collaboration with the electric company on the common problems of corrosion and electrolysis, taking the following factors into consideration:

(a) The possibility of the pipeline carrying either unbalanced line currents or fault currents.

(b) The possibility of lightning or fault currents inducing voltages sufficient to puncture pipe coating or pipe.

(c) Cathodic protection of the pipeline, including location of ground beds, especially if the electric line is carried on steel towers.

(d) Bonding connections between the pipeline and either the steel tower footings or the buried ground facilities or the groundwire of the overhead electric system.

863.4 Investigate the necessity of protecting insulating joints in the pipeline against induced voltages or currents resulting from lightning strokes. Such protection can be obtained by connecting buried sacrificial anodes to the pipe near the insulating joints or by bridging the pipeline insulator with a sparkgap or by other effective means. * * *

WORKING PRESSURES OF PIPE

(Based on ASA Code B 31.8-1958)

Introduction and Explanation of Tables

The following tables give as basic information the nominal size, outside diameter, weight per foot, wall thickness, and mill test pressure as specified in the standard of the pipe under consideration.

Working pressures, based on the standard mill test pressure, are given in Column "1" in all the tables. These pressures, as defined in Par. 841.14 (b) of the ASA Code B 31.8-1958, shall not exceed 85% of the mill test pressure, unless a higher hydrostatic test pressure is placed on the pipe either before or after installation.

For API standard 5L Grade B seamless and electric weld pipe, (Table 2), the standard mill test pressure is based on stressing the metal to 60% of its specified minimum yield strength, with a maximum test pressure of 2500 psi. Allowable working pressure of 85% of standard mill test pressure results in stressing the steel only 51% or less of its specified minimum yield strength.

The code, however, permits use of 72% specified minimum yield strength for Type A construction and 60% for Type B construction.

To operate at these higher working pressures, the code requires that the pipe be retested hydrostatically either before or after installation, or to specify a higher than standard mill test pressure when ordering.

Minimum hydrostatic test pressures are:

Type A Construction . . .	110% of working pressure
Type B Construction . . .	125% of working pressure
Type C Construction . . .	140% of working pressure
Type D Construction . . .	140% of working pressure

Maximum hydrostatic test pressures allowed under the code are shown in Column "2"; these are the pressures that would result in stressing the metal to 85% of its specified minimum yield strength.

For API standard 5LX-42 pipe, mill test pressure is 75% of specified minimum yield strength in size 8.625-in. OD and smaller, and 85% for sizes of 10.75-in. OD and larger, up to a maximum of 3000 psi. Maximum working pressure based on 85% of this mill test pressure is shown in Column "1" in Table 3.

For Type A construction, working pressures are based on stressing the metal to 72% of specified minimum yield strength.

For sizes 8.625-in. OD and smaller, mill test pressure for 5LX-42 is 75% of minimum yield and maximum working pressure is based on 85% of mill test pressure; thus we have $.85 \times .75 = 63.75\%$ of specified minimum yield strength. To have a working pressure based on 72% of minimum yield, for 8.625-in. OD and smaller, a hydrostatic test higher than standard mill test must be made either before or after installation.

On sizes 10.75-in. OD and larger, API 5LX-42 mill test pressure is 85% of minimum yield and maximum working pressure is based on 85% of this mill test pressure, giving $.85 \times .85 = 72.25\%$ of specified minimum yield strength. The code limits working pressure to 72% of minimum yield.

Except in those sizes and wall thicknesses that have a mill test pressure limited by the maximum of 3000 psi, the maximum working pressures for API 5LX-42 for Type A in sizes 10.75-in. OD and larger are shown in Column "3" in Table 3 and will not require hydrostatic testing after installation for Type A Construction. In sizes and wall thicknesses limited to 3000 psi standard mill test pressure, hydrostatic testing after installation will be required to use the higher working pressures in Column "3" as contrasted to those in Column "1."

Working pressures of these tables are based on temperatures less than 250 F. Any higher temperature requires a derating of working pressure, as follows:

250 F or less	1.000
300 F	0.967
350 F	0.933
400 F	0.900
450 F	0.867

For intermediate temperatures, interpolate for factor.

Compressor Stations. Table 841.141 of the code defines minimum wall thicknesses of the various sizes of pipe for different location classes and also for compressor station gas piping. If calculated wall thickness for desired working pressure is less than these minimums, the minimums in the table must be used.

Other types of construction: Refer to Paragraphs 841 and 841.01; the table under Paragraphs 841.02, 841.03, and 841.04; Paragraph 841.142; and Paragraph 841.143.

Examples

Problem: Determine wall thickness of 12-in. pipe for 800 psi working pressure for Class 1 location, Type "A" construction, less than 250 F operating temperature.

1. *To use API 5L Grade B Seamless or Electric Weld:*

From Table 2, under Column "3", (Working Pressure Type "A" Construction) select 12.75 OD pipe. Pipe of this size with a .219-in. wall satisfies the requirement as it has a maximum working pressure of 865 psi.

If this pipe is purchased from mill, a mill test pressure of 950 psi must be specified on purchase order as standard mill test pressure is only 700 psi.

If pipe is on hand and has had only standard mill test pressure, it must be tested hydrostatically to 950 psi either before or after installation. If tested after installation, no further testing is necessary. If tested to 950 psi before installation, it will have to be tested to 880 psi with gas or hydrostatically after installation ($800 \times 110\%$).

2. *To use API 5LX-42 Pipe:*

From Table 3, under Column "3", (Working Pressure Type "A" Construction) select 12.75 OD pipe. Pipe of this size with a .203-in. wall meets requirements, as it has a maximum working pressure of 963 psi.

If pipe of this size and grade is used, a test pressure of 880 psi (110% of working pressure of 800 psi) is required, after installation, using gas or hydrostatic. Standard mill test pressure is 1140 psi and pipe conforms to code for conditions under consideration.

Problem: Determine wall thickness of 12-in. pipe for 800 psi working pressure for Class 3 location, Type "C" construction (compressor station), less than 250 F operating temperature.

1. *To use API 5L Grade B Seamless or Electric Weld:*

From Table 2, under Column "5", (Working Pressure Type "C" Construction) select 12.75 OD pipe of .312-in. wall (maximum working pressure of 857 psi).

This pipe will have to be hydrostatically tested to 140% (1120 psi) of its working pressure after installation. If to be purchased from mill, a mill test pressure of 1120 psi should be specified (standard mill test is 1000 psi).

If pipe is on hand, the hydrostatic test of 1120 psi after installation will suffice.

Wall thickness is greater than the minimum of .250-in. required for compressor station piping and therefore conforms to the code.

2. *To use API 5LX-42 Pipe:*

From Table 3, under Column "5", (Working Pressure Type "C" Construction) select 12.75 OD pipe of .250-in. wall (maximum working pressure 824 psi).

Standard mill test pressure for this pipe is 1410 psi, which is greater than the 140% (1120 psi) hydrostatic test pressure required after installation. Note also that the .250-in. wall is the thinnest that can be used in 12.75 OD pipe for compressor station piping in conformity with the code.

WORKING PRESSURES OF PIPE

(Based on ASA Code B 31.8-1958)

Table 1

Non-API Standard Grade B Seamless and Electric-Weld Pipe

(Specified Minimum Yield Strength — 35,000 psi)

Nominal Size (in.)	Outside Diameter (in.)	Weight (lb/ft)	Wall Thickness (in.)	2 Maximum Hydrostatic Test Pressure (psi)	3 Working Pressure Type "A" Construction (psi)	4 Working Pressure Type "B" Construction (psi)	5 Working Pressure, Type "C" Construction (psi)	6 Working Pressure, Type "D" Construction (psi)
1	1.315	2.561	.219	9908	8393	6994	5829	4663
		2.850	.250	11311	9581	7984	6654	5323
1¼	1.660	3.764	.250	8961	7590	6325	5271	4217
1½	1.900	4.862	.281	8799	7453	6211	5176	4141
2	2.375	3.938	.167	4184	3544	2953	2461	1969
		4.330	.188	4710	3990	3325	2771	2216
		5.673	.250	6263	5305	4421	3684	2947
		6.883	.312	7816	6620	5517	4598	3678
		7.450	.343	8593	7278	6065	5055	4044
2½	2.875	6.160	.217	4491	3804	3170	2642	2113
		10.01	.375	7761	6574	5478	4565	3652
3	3.500	5.30	.148	2516	2131	1776	1480	1184
		8.39	.241	4097	3470	2892	2410	1928
		8.80	.254	4318	3658	3048	2540	2032
		9.91	.289	4913	4162	3468	2890	2312
		10.64	.312	5304	4493	3744	3120	2496
		13.42	.406	6902	5846	4872	4060	3248
		14.30	.437	7429	6293	5244	4370	3496
4	4.500	5.99	.128	1692	1434	1195	996	796
		6.26	.134	1771	1500	1250	1042	834
		6.61	.142	1877	1590	1325	1104	883
		7.64	.165	2181	1848	1540	1283	1026
		9.39	.205	2710	2295	1913	1594	1275
		12.24	.271	3583	3035	2529	2108	1686
		13.42	.300	3966	3360	2300	2333	1866
		14.00	.312	4125	3494	2912	2427	1941
		16.52	.375	4958	4200	3500	2917	2332
		19.00	.437	5778	4895	4079	3399	2719
		21.36	.500	6611	5600	4667	3889	3111
		22.60	.531	7021	5947	4956	4130	3304
6	6.625	10.78	.156	1401	1187	989	824	659
		11.56	.169	1517	1285	1071	893	714
		12.50	.180	1616	1369	1141	951	760
		18.86	.277	2487	2107	1756	1463	1170
		32.79	.500	4490	3804	3170	2642	2113
		36.40	.562	5047	4275	3563	2969	2375
		45.30	.718	6448	5462	4552	3793	3034
8	8.625	14.26	.158	1090	923	769	641	513
		14.95	.165	1138	964	803	670	536
		18.30	.203	1400	1186	988	824	659
		21.43	.238	1641	1390	1159	966	772
		31.00	.352	2428	2056	1714	1428	1142
		35.70	.406	2801	2372	1977	1648	1318
		40.83	.469	3235	2740	2284	1903	1522
		50.90	.593	4090	3465	2887	2406	1925
		53.40	.625	4311	3652	3043	2536	2028
		60.70	.718	4953	4195	3496	2914	2331
		67.80	.812	5602	4745	3954	3295	2636
		74.70	.906	6250	5294	4412	3677	2941
10	10.75	22.86	.203	1124	952	793	661	529
		38.66	.348	1921	1627	1356	1130	904
		43.68	.395	2186	1852	1543	1286	1029
		57.98	.531	2939	2490	2075	1729	1383
		64.40	.593	3282	2780	2317	1931	1544
		77.00	.718	3974	3366	2805	2338	1870
		80.10	.750	4151	3516	2930	2442	1954
		89.20	.843	4943	4187	3489	2903	2326
		104.20	1.000	5535	4689	3907	3256	2605
		109.90	1.063	5884	4984	4153	3461	2769
		116.00	1.125	6227	5275	4396	3663	2930
12	12.75	27.20	.203	947	803	669	558	446
		31.81	.238	1111	941	784	654	523
		37.16	.279	1302	1103	919	766	613
		39.89	.300	1400	1186	988	824	658
		53.52	.406	1895	1605	1337	1115	891
		73.22	.562	2622	2221	1851	1543	1234
		80.94	.625	2916	2470	2059	1716	1372
		88.5	.687	3206	2716	2263	1886	1509
		107.20	.843	3934	3332	2777	2314	1851
		111.00	.875	4033	3459	2882	2402	1922
		125.5	1.000	4667	3953	3294	2745	2196
		139.7	1.125	5250	4447	3706	3088	2470
		150.12	1.219	5689	4819	4016	3347	2677
		160.30	1.312	6123	5186	4322	3602	2881

WORKING PRESSURES OF PIPE

(Based on ASA Code B 31.8-1958)

Table 1, Page 2

Non-API Standard Grade B Seamless and Electric-Weld Pipe

(Specified Minimum Yield Strength — 35,000 psi)

Nominal Size (in.)	Outside Diameter (in.)	Weight (lb/ft)	Wall Thickness (in.)	2 Maximum Hydrostatic Test Pressure (psi)	3 Working Pressure Type "A" Construction (psi)	4 Working Pressure Type "B" Construction (psi)	5 Working Pressure, Type "C" Construction (psi)	6 Working Pressure, Type "D" Construction (psi)
14	14	27.73	.188	799	677	564	470	376
		32.20	.220	935	792	660	550	440
		34.98	.238	1012	857	714	595	476
		58.94	.406	1726	1462	1218	1015	812
		67.78	.469	1993	1688	1407	1173	933
		84.91	.593	2520	2135	1779	1483	1186
		89.28	.625	2656	2250	1875	1563	1250
		93.49	.656	2788	2362	1968	1640	1312
		106.13	.750	3133	2700	2250	1875	1500
		130.72	.937	3932	3373	2811	2343	1874
		150.66	1.093	4645	3935	3279	2733	2186
		170.21	1.250	5313	4500	3750	3125	2500
		181.66	1.344	5712	4838	4032	3360	2688
		189.11	1.406	5976	5062	4218	3515	2812
16	16	31.75	.188	700	593	494	412	329
		39.23	.233	884	750	625	521	416
		67.62	.406	1509	1278	1066	888	710
		77.79	.469	1743	1477	1231	1025	820
		87.72	.531	1975	1673	1394	1162	929
		107.50	.656	2439	2066	1722	1435	1148
		112.35	.687	2554	2164	1803	1503	1202
		122.15	.750	2788	2362	1969	1641	1312
		136.46	.843	3134	2655	2213	1844	1475
		164.82	1.031	3834	3248	2707	2256	1804
		192.28	1.218	4530	3837	3197	2665	2132
		223.50	1.437	5344	4527	3772	3144	2515
		232.29	1.500	5579	4725	3938	3282	2625
		240.85	1.562	5809	4920	4100	3417	2734
18	18	104.66	.562	1858	1574	1312	1093	874
		110.42	.594	1964	1663	1386	1155	924
		115.98	.625	2066	1750	1459	1216	972
		132.52	.718	2373	2010	1675	1396	1117
		138.17	.750	2479	2100	1750	1459	1167
		149.05	.812	2634	2274	1895	1579	1263
		170.75	.937	3097	2624	2186	1822	1458
		207.96	1.156	3322	3237	2698	2248	1798
		244.14	1.375	4545	3850	3208	2674	2139
		274.22	1.562	5163	4373	3644	3037	2430
		293.91	1.687	5577	4724	3937	3281	2624
		303.71	1.750	5785	4900	4084	3403	2722
20	20	116.67	.562	1672	1416	1180	984	787
		122.90	.593	1765	1495	1246	1038	830
		129.33	.625	1860	1575	1313	1094	875
		166.40	.812	2416	2046	1705	1421	1137
		178.72	.875	2603	2205	1838	1532	1225
		184.75	.906	2695	2283	1903	1586	1268
		208.87	1.031	3068	2598	2165	1805	1444
		250.31	1.250	3719	3150	2625	2188	1750
		256.09	1.281	3811	3228	2690	2242	1794
		296.37	1.500	4463	3780	3150	2625	2100
		341.09	1.750	5206	4410	3675	3063	2450
		357.56	1.844	5605	4748	3956	3297	2638
		373.67	1.937	5763	4882	4068	3390	2712
22	22	58.07	.250	676	572	477	398	318
		142.68	.625	1690	1431	1193	995	796
		170.21	.750	2028	1718	1432	1193	954
		197.41	.875	2366	2004	1670	1392	1114
		224.28	1.000	2705	2291	1909	1591	1273
24	24	63.41	.250	620	525	437	365	292
		140.67	.562	1393	1180	983	820	656
		156.03	.625	1550	1313	1094	912	729
		171.05	.687	1703	1443	1202	1002	802
		186.23	.750	1860	1575	1313	1094	875
		238.10	.968	2340	2032	1694	1412	1129
		252.91	1.031	2556	2165	1804	1504	1203
		296.35	1.218	3012	2551	2126	1772	1417
		360.45	1.500	3719	3150	2625	2188	1750
		415.85	1.750	4338	3675	3062	2552	2042
		483.12	2.062	5112	4330	3608	3007	2406
		509.49	2.187	5422	4593	3827	3190	2552
		535.52	2.312	5732	4855	4046	3372	2697
26	26	83.73	.312	714	605	504	420	336
		102.63	.375	859	727	606	505	404
		119.44	.438	1102	849	707	590	472
		136.17	.500	1144	969	808	673	538
		152.68	.562	1286	1089	908	757	605
		169.37	.625	1431	1212	1010	842	673
		177.56	.656	1501	1272	1060	883	706
		202.25	.750	1716	1454	1211	1010	808
		218.43	.812	1859	1575	1312	1094	875
		234.79	.875	2003	1696	1414	1178	942
		251.07	.938	2146	1818	1515	1263	1010
		267.00	1.000	2288	1939	1616	1347	1077

WORKING PRESSURES OF PIPE

(Based on ASA Code B 31.8-1958)

Table 2

API Standard 5L Grade B Seamless and Electric Weld Pipe

(Specified Minimum Yield Strength — 35,000 psi)

Nominal Size (in.)	Outside Diameter (in.)	Weight (lb/ft)	Wall Thickness (in.)	Specified Mill Test Pressure (psi)	1 85% of Mill Test Pressure (psi)	2 Maximum Hydrostatic Test Pressure (psi)	3 Working Pressure, Type "A" Construction (psi)	4 Working Pressure, Type "B" Construction (psi)	5 Working Pressure, Type "C" Construction (psi)	6 Working Pressure, Type "D" Construction (psi)
⅛	0.405	0.24	0.068	700	595	9990	8462	7052	5877	4701
		0.31	0.095	850	722	13956	11822	9851	8210	6568
¼	0.540	0.42	0.088	700	595	9695	8213	6844	5704	4563
		0.54	0.119	850	722	13112	11107	9256	7713	6170
⅜	0.675	0.57	0.091	700	595	8021	6795	5662	4719	3775
		0.74	0.126	850	722	11106	9408	7840	6533	5226
½	0.840	0.85	0.109	700	595	7721	6540	5450	4541	3633
		1.09	0.147	850	722	10413	8820	7350	6125	4900
		1.71	0.294	1000	850	20825	17640	14700	12250	9800
¾	1.050	1.13	0.133	700	595	7537	6384	5320	4434	3547
		1.47	0.154	850	722	8727	7392	6160	5134	4107
		2.44	0.308	1000	850	17453	14784	12320	10267	8213
1	1.315	1.68	0.133	700	595	6017	5097	4247	3540	2832
		2.17	0.179	850	722	8099	6860	5717	4764	3811
		3.66	0.358	1000	850	19057	13721	11434	9529	7623
1¼	1.660	2.27	0.140	1300	1105	5017	4250	3542	2952	2361
		3.00	0.191	1900	1615	6846	5799	4832	4027	3222
		5.21	0.382	2300	1955	13692	11598	9665	8054	6443
1½	1.900	2.72	0.145	1300	1105	4540	3846	3205	2671	2137
		3.63	0.200	1900	1615	6262	5305	4421	3684	2947
		6.41	0.400	2300	1955	12526	10611	8842	7369	5895
2	2.375	3.65	0.154	1300	1105	3857	3267	2723	2269	1815
		5.02	0.218	1900	1615	5461	4626	3855	3213	2570
		9.03	0.436	2300	1955	10923	9252	7710	6425	5140
2½	2.875	5.79	0.203	1300	1105	4200	3558	2965	2471	1977
		7.66	0.276	1900	1615	5712	4838	4032	3360	2688
		13.70	0.552	2300	1955	11424	9677	8064	6720	5376
3	3.500	4.51	0.125	1500	1275	2125	1800	1500	1250	1000
		5.58	0.156	1900	1615	2652	2246	1872	1560	1248
		6.63	0.188	2200	1870	3196	2707	2256	1880	1504
		7.58	0.216	2500	2125	3672	3110	2592	2160	1728
		8.68	0.250	2500	2125	4250	3600	3000	2500	2000
		9.67	0.281	2500	2125	4777	4046	3372	2810	2248
		10.25	0.300	2500	2125	5100	4320	3600	3000	2400
		18.58	0.600	2500	2125	10200	8640	7200	6000	4300
4	4.500	5.84	0.125	1200	1020	1653	1400	1167	973	778
		7.25	0.156	1500	1275	2063	1747	1456	1214	971
		8.64	0.188	1800	1530	2486	2106	1755	1463	1170
		10.00	0.219	2000	1700	2896	2453	2044	1704	1363
		10.79	0.237	2200	1870	3134	2655	2212	1844	1475
		11.35	0.250	2300	1955	3306	2800	2333	1945	1556
		12.67	0.281	2500	2125	3715	3147	2623	2186	1748
		13.98	0.312	2500	2125	4125	3494	2912	2427	1941
		14.98	0.337	2500	2125	4456	3774	3145	2621	2097
		27.54	0.674	2500	2125	8911	7548	6290	5242	4194
6	6.625	12.89	0.188	1200	1020	1688	1430	1192	993	794
		14.97	0.219	1400	1190	1967	1666	1388	1157	926
		17.02	0.250	1600	1360	2247	1902	1585	1321	1057
		18.97	0.280	1800	1530	2514	2130	1775	1479	1183
		21.07	0.312	2000	1700	2802	2374	1978	1649	1319
		23.06	0.344	2200	1870	3090	2617	2181	1818	1454
		25.03	0.375	2400	2040	3368	2853	2377	1981	1585
		28.57	0.432	2500	2125	3879	3286	2738	2282	1826
		53.16	0.864	2500	2125	7760	6573	5477	4565	3652

WORKING PRESSURES OF PIPE, Table 2, Page 2

API Standard 5L Grade B Seamless and Electric Weld Pipe

(Specified Minimum Yield Strength — 35,000 psi)

Nominal Size (in.)	Outside Diameter (in.)	Weight (lb/ft)	Wall Thickness (in.)	Specified Mill Test Pressure (psi)	1 85% of Mill Test Pressure (psi)	2 Maximum Hydrostatic Test Pressure (psi)	3 Working Pressure, Type "A" Construction (psi)	4 Working Pressure, Type "B" Construction (psi)	5 Working Pressure, Type "C" Construction (psi)	6 Working Pressure, Type "D" Construction (psi)
8	8.625	16.90	0.188	900	765	1297	1099	916	763	610
		19.64	0.219	1100	935	1510	1279	1066	889	711
		22.36	0.250	1200	1020	1725	1461	1217	1015	812
		24.70	0.277	1300	1105	1911	1619	1349	1124	899
		27.74	0.312	1500	1275	2152	1823	1519	1266	1013
		28.55	0.322	1600	1360	2221	1881	1568	1307	1045
		30.40	0.344	1700	1445	2373	2010	1675	1396	1117
		33.04	0.375	1800	1530	2587	2192	1826	1522	1218
		38.26	0.438	2100	1785	3022	2560	2133	1778	1422
		43.39	0.500	2400	2040	3449	2921	2434	2029	1623
		72.42	0.875	2500	2125	6036	5113	4261	3551	2840
10	10.75	21.15	0.188	750	638	1040	881	734	612	490
		24.60	0.219	850	723	1212	1027	856	713	570
		28.04	0.250	1000	850	1384	1172	977	814	651
		31.20	0.279	1200	1020	1544	1308	1090	909	727
		34.24	0.307	1200	1020	1699	1439	1199	1000	800
		38.20	0.344	1300	1105	1904	1613	1344	1120	896
		40.48	0.365	1400	1190	2020	1711	1426	1189	951
		48.19	0.438	1700	1445	2424	2053	1711	1426	1141
		54.74	0.500	2000	1700	2768	2344	1954	1628	1302
12	12.75	29.28	0.219	700	595	1022	865	721	601	448
		33.38	0.250	800	680	1167	989	824	687	549
		37.45	0.281	950	808	1312	1111	926	772	617
		41.51	0.312	1000	850	1456	1233	1028	857	685
		43.77	0.330	1200	1020	1540	1305	1087	906	725
		45.55	0.344	1200	1020	1606	1360	1133	945	756
		49.56	0.375	1200	1020	1750	1482	1235	1030	824
		57.53	0.438	1400	1190	2044	1732	1443	1203	962
		65.42	0.500	1600	1360	2333	1976	1647	1373	1098
14	14	36.71	0.250	750	638	1063	900	750	625	500
		41.25	0.281	850	722	1194	1012	843	703	562
		45.68	0.312	950	808	1326	1123	963	780	624
		50.14	0.344	1000	850	1462	1238	1032	860	688
		54.57	0.375	1100	935	1594	1350	1125	938	750
		63.37	0.438	1300	1105	1862	1577	1314	1095	876
		72.09	0.500	1500	1275	2125	1800	1500	1250	1000
16	16	42.05	0.250	650	553	930	788	656	547	438
		47.22	0.281	750	638	1045	885	737	615	492
		52.36	0.312	800	680	1160	938	819	683	546
		57.48	0.344	900	765	1279	1084	903	753	602
		62.58	0.375	1000	850	1395	1182	985	821	656
		72.72	0.438	1100	935	1629	1380	1150	958	766
		82.77	0.500	1300	1105	1860	1575	1313	1094	875
18	18	47.39	0.250	600	510	826	700	583	486	389
		53.22	0.281	650	553	929	787	656	547	437
		59.03	0.312	750	638	1031	873	728	607	485
		64.82	0.344	800	680	1137	963	803	669	535
		70.59	0.375	900	765	1239	1050	875	729	583
		82.06	0.438	1000	850	1448	1226	1022	852	681
		93.45	0.500	2200	1020	1653	1400	1167	973	778
20	20	52.73	0.250	500	425	744	630	525	438	350
		59.23	0.281	600	510	836	708	590	492	394
		65.71	0.312	650	553	928	788	655	546	437
		72.16	0.344	700	595	1023	867	722	602	482
		78.60	0.375	800	680	1116	945	788	657	525
		91.41	0.438	900	765	1303	1104	920	767	613
		104.13	0.500	1000	850	1488	1260	1050	875	700
22	22	72.38	0.312	600	510	844	715	596	497	397
		79.51	0.344	650	553	931	788	657	548	438
		86.61	0.375	700	595	1014	859	716	591	477
		100.75	0.438	850	723	1185	1004	836	697	558
		114.81	0.500	950	808	1352	1146	955	796	656
24	24	79.06	0.312	550	468	744	655	546	455	365
		86.85	0.344	600	510	853	722	602	502	401
		94.62	0.375	650	553	930	788	656	547	438
		110.10	0.438	750	638	1086	920	767	639	511
		125.49	0.500	850	723	1239	1050	875	730	584

WORKING PRESSURES OF PIPE

(Based on ASA Code B 31.8-1958)

Table 3

API Standard 5LX-42 — Electric Resistance Welded, Electric Flash Welded and Submerged Arc Welded Pipe

(Specified Minimum Yield Strength — 42,000 psi)

Nominal Size (in.)	Outside Diameter (in.)	Weight (lb/ft)	Wall Thickness (in.)	Specified Mill Test Pressure (psi)	1 85% of Mill Test Pressure (psi)	2 Maximum Hydrostatic Test Pressure (psi)	3 Working Pressure, Type "A" Construction (psi)	4 Working Pressure, Type "B" Construction (psi)	5 Working Pressure, Type "C" Construction (psi)	6 Working Pressure, Type "D" Construction (psi)
6	6.625	12.89	0.188	1790	1522	2026	1716	1430	1192	954
		14.97	0.219	2090	1777	2360	1999	1666	1389	1111
		17.02	0.250	2380	2023	2695	2282	1902	1585	1268
		18.97	0.280	2670	2270	3018	2556	2130	1775	1420
		21.07	0.312	2970	2525	3363	2848	2374	1978	1582
		23.06	0.344	3000	2550	3708	3141	2617	2181	1745
		25.03	0.375	3000	2550	4042	3424	2853	2378	1902
		28.57	0.432	3000	2550	4655	3944	3286	2739	2191
8	8.625	16.90	0.188	1380	1173	1556	1318	1099	916	732
		18.27	0.203	1490	1267	1680	1423	1186	989	791
		19.64	0.219	1600	1360	1813	1536	1280	1067	853
		22.36	0.250	1830	1556	2070	1753	1461	1218	974
		24.70	0.277	2030	1726	2293	1943	1619	1349	1079
		27.74	0.312	2280	1938	2583	2188	1823	1520	1216
		28.55	0.322	2360	2006	2666	2258	1882	1568	1254
		30.40	0.344	2520	2142	2848	2412	2010	1675	1340
		33.04	0.375	2740	2329	3104	2629	2191	1826	1461
		38.26	0.438	3000	2550	3626	3072	2560	2133	1706
		43.39	0.500	3000	2550	4140	3506	2922	2435	1948
10	10.75	21.15	0.188	1250	1063	1249	1058	881	735	588
		22.88	0.203	1350	1148	1348	1142	952	793	634
		24.60	0.219	1460	1241	1454	1232	1027	856	684
		28.04	0.250	1670	1420	1661	1407	1172	977	782
		31.20	0.279	1860	1581	1853	1570	1308	1090	872
		34.24	0.307	2040	1734	2039	1727	1439	1200	960
		38.20	0.344	2290	1947	2285	1935	1613	1344	1075
		40.48	0.365	2430	2066	2424	2053	1711	1426	1141
		48.19	0.438	2910	2474	2910	2465	2054	1712	1369
		54.74	0.500	3000	2550	3321	2813	2344	1954	1563
12	12.75	27.22	0.203	1140	969	1136	963	802	669	535
		29.28	0.219	1230	1046	1227	1039	866	722	577
		33.38	0.250	1410	1199	1400	1186	988	824	659
		37.45	0.281	1580	1343	1573	1333	1111	926	740
		41.51	0.312	1750	1488	1747	1480	1233	1028	822
		43.77	0.330	1850	1573	1848	1565	1304	1087	870
		45.55	0.344	1930	1641	1926	1632	1360	1133	906
		49.56	0.375	2100	1785	2100	1779	1483	1236	988
		53.56	0.406	2280	1938	2274	1926	1605	1338	1070
		57.53	0.438	2460	2091	2453	2078	1732	1443	1154
		65.42	0.500	2810	2389	2800	2372	1976	1647	1318
14	14	30.93	0.210	1080	918	1071	907	756	630	504
		32.20	0.219	1120	952	1117	946	788	657	525
		36.71	0.250	1280	1088	1275	1080	900	750	600
		41.21	0.281	1440	1224	1433	1214	1012	843	674
		45.68	0.312	1600	1360	1591	1348	1123	936	749
		50.14	0.344	1760	1496	1754	1486	1238	1032	826
		54.57	0.375	1920	1632	1913	1620	1350	1125	900
		63.37	0.438	2240	1904	2234	1892	1577	1314	1051
		72.09	0.500	2550	2168	2550	2160	1800	1500	1200
16	16	36.87	0.219	980	833	978	828	690	575	460
		42.05	0.250	1120	952	1116	945	788	657	525
		47.22	0.281	1260	1071	1254	1062	885	738	590
		52.36	0 312	1400	1190	1392	1175	983	819	655
		57.48	0.344	1540	1309	1535	1300	1084	903	722
		62.58	0.375	1680	1428	1673	1418	1181	985	788
		72.72	0.438	1960	1666	1955	1659	1380	1150	920
		82.77	0.500	2240	1904	2231	1890	1575	1313	1050

WORKING PRESSURES OF PIPE

(Based on ASA Code B 31.8-1958)

Table 3, Page 2

API Standard 5LX-42 — Electric Resistance Welded, Electric Flash Welded and Submerged Arc Welded Pipe

(Specified Minimum Yield Strength — 42,000 psi)

Nominal Size (in.)	Outside Diameter (in.)	Weight (lb/ft)	Wall Thickness (in.)	Specified Mill Test Pressure (psi)	1 85% of Mill Test Pressure (psi)	2 Maximum Hydrostatic Test Pressure (psi)	3 Working Pressure, Type "A" Construction (psi)	4 Working Pressure, Type "B" Construction (psi)	5 Working Pressure, Type "C" Construction (psi)	6 Working Pressure, Type "D" Construction (psi)
		47.39	0.250	1000	850	992	840	700	584	467
		53.22	0.281	1120	952	1114	943	787	656	524
		59.03	0.312	1240	1054	1238	1048	874	728	582
18	18	64.82	0.344	1370	1165	1364	1156	963	803	642
		70.59	0.375	1490	1267	1488	1260	1050	875	700
		76.34	0.406	1620	1377	1611	1364	1137	948	758
		82.06	0.438	1740	1479	1737	1472	1226	1022	818
		93.45	0.500	1990	1692	1984	1680	1400	1167	934
		52.73	0.250	900	765	893	756	630	525	420
		59.23	0.281	1010	859	1003	850	708	590	472
		65.71	0.312	1120	952	1114	943	786	655	524
20	20	72.16	0.344	1230	1046	1228	1040	867	723	578
		78.60	0.375	1340	1139	1339	1134	945	788	630
		85.01	0.406	1450	1233	1449	1228	1023	858	682
		91.41	0.438	1570	1335	1564	1325	1104	920	736
		104.13	0.500	1790	1522	1785	1512	1260	1050	840
		58.07	0.250	820	697	812	688	573	478	382
		65.24	0.281	920	782	912	773	644	537	429
		72.38	0.312	1020	867	1013	858	715	596	477
22	22	79.51	0.344	1120	952	1116	945	788	657	525
		86.61	0.375	1220	1037	1217	1031	859	716	573
		93.69	0.406	1320	1122	1318	1116	930	775	620
		100.75	0.438	1430	1216	1421	1204	1003	836	669
		114.81	0.500	1630	1386	1623	1374	1145	955	764
		63.41	0.250	750	638	744	630	525	438	350
		71.25	0.281	840	714	836	708	590	492	394
		79.06	0.312	930	791	928	786	655	546	437
24	24	86.85	0.344	1030	876	1023	867	722	602	482
		94.62	0.375	1120	952	1116	945	788	657	525
		102.37	0.406	1210	1029	1208	1023	853	711	568
		110.10	0.438	1310	1114	1303	1104	920	767	613
		125.49	0.500	1490	1267	1488	1260	1050	875	700
		68.75	0.250	690	587	687	582	485	404	323
		77.25	0.281	780	663	772	654	545	454	363
		85.73	0.312	860	731	857	726	605	504	403
26	26	94.19	0.344	950	808	944	800	667	556	444
		102.63	0.375	1030	876	1030	873	727	606	485
		111.05	0.406	1120	952	1115	945	787	656	525
		119.44	0.438	1210	1029	1203	1019	849	708	566
		136.17	0.500	1380	1173	1373	1163	969	808	646
		74.09	0.250	640	544	638	540	450	375	300
		83.26	0.281	720	612	717	607	506	422	337
		92.41	0.312	800	680	796	674	562	468	374
28	28	101.53	0.344	880	748	877	743	619	516	413
		110.64	0.375	960	816	956	810	675	563	450
		119.72	0.406	1040	884	1035	877	731	609	487
		128.79	0.438	1120	952	1117	946	788	657	526
		146.85	0.500	1280	1088	1275	1080	900	750	600
		79.43	0.250	600	510	595	504	420	350	280
		89.27	0.281	670	570	670	567	472	394	315
		99.08	0.312	750	638	742	629	524	437	349
30	30	108.88	0.344	820	697	819	693	578	487	385
		118.65	0.375	900	765	893	756	630	525	420
		128.40	0.406	970	825	966	819	682	569	455
		138.13	0.438	1050	893	1042	883	736	613	490
		157.53	0.500	1200	1020	1190	1008	840	700	560

WORKING PRESSURES OF PIPE

(Based on ASA Code B 31.8-1958)

Table 4

API Standard 5LX-46 — Seamless, Electric Resistance Welded, Electric Flash Welded, and Submerged Arc Welded Pipe

(Specified Minimum Yield Strength — 46,000 psi)

Nominal Size (in.)	Outside Diameter (in.)	Weight (lb/ft)	Wall Thickness (in.)	Specified Mill Test Pressure (psi)	1 85% of Mill Test Pressure (psi)	2 Maximum Hydrostatic Test Pressure (psi)	3 Working Pressure, Type "A" Construction (psi)	4 Working Pressure, Type "B" Construction (psi)	5 Working Pressure, Type "C" Construction (psi)	6 Working Pressure, Type "D" Construction (psi)
6	6.625	12.89	0.188	1960	1660	2219	1879	1566	1305	1044
		14.97	0.219	2290	1947	2585	2190	1825	1521	1216
		17.02	0.250	2610	2219	2950	2499	2083	1736	1388
		18.97	0.280	2920	2482	3305	2799	2333	1944	1555
		21.07	0.312	3000	2550	3683	3120	2600	2167	1733
		23.06	0.344	3000	2550	4060	3439	2866	2389	1911
		25.03	0.375	3000	2550	4427	3750	3125	2604	2083
		28.57	0.432	3000	2550	5099	4319	3599	3000	2400
8	8.625	16.90	0.188	1510	1284	1704	1444	1203	1003	802
		18.27	0.203	1630	1386	1840	1559	1299	1083	866
		19.64	0.219	1760	1496	1986	1682	1402	1168	934
		22.36	0.250	2010	1709	2266	1920	1600	1333	1066
		24.70	0.277	2220	1887	2511	2127	1772	1477	1182
		27.74	0.312	2500	2125	2829	2396	1997	1664	1331
		28.55	0.322	2580	2193	2919	2472	2060	1717	1374
		30.40	0.344	2760	2346	3119	2642	2201	1836	1468
		33.04	0.375	3000	2550	3400	2880	2400	2000	1600
		38.26	0.438	3000	2550	3971	3664	2803	2336	1869
		43.39	0.500	3000	2550	4533	3840	3200	2667	2133
10	10.75	21.15	0.188	1370	1165	1366	1158	965	804	643
		22.88	0.203	1480	1258	1476	1251	1042	869	695
		24.60	0.219	1600	1360	1593	1349	1124	937	750
		28.04	0.250	1820	1547	1819	1541	1284	1070	856
		31.20	0.279	2030	1726	2030	1719	1433	1194	955
		34.20	0.307	2240	1904	2233	1819	1576	1314	1051
		38.20	0.344	2510	2134	2502	2120	1766	1472	1178
		40.48	0.365	2660	2261	2655	2249	1874	1562	1250
		48.19	0.438	3000	2550	3186	2699	2249	1874	1499
		54.74	0.500	3000	2550	3637	3081	2567	2140	1712
12	12.75	27.22	0.203	1250	1063	1245	1055	879	733	586
		29.28	0.219	1350	1148	1343	1138	948	790	632
		33.38	0.250	1540	1309	1533	1299	1082	902	722
		37.45	0.281	1730	1471	1724	1460	1217	1014	811
		41.51	0.312	1920	1632	1913	1621	1351	1126	900
		43.77	0.330	2030	1726	2024	1714	1429	1191	952
		45.55	0.344	2110	1794	2110	1787	1489	1241	993
		49.56	0.375	2300	1955	2300	1948	1624	1352	1082
		53.56	0.406	2490	2117	2491	2110	1758	1465	1172
		57.53	0.438	2690	2287	2686	2275	1896	1580	1264
		65.42	0.500	3000	2550	3067	2598	2165	1804	1443
14	14	30.93	0.210	1180	1003	1173	994	828	690	552
		32.20	0.219	1230	1046	1223	1036	863	720	576
		36.71	0.250	1400	1190	1397	1183	985	822	657
		41.21	0.281	1570	1335	1570	1330	1108	924	739
		45.68	0.312	1750	1488	1743	1476	1230	1025	820
		50.14	0.344	1930	1641	1922	1628	1357	1131	904
		54.57	0.375	2100	1785	2094	1774	1478	1232	986
		63.37	0.438	2450	2083	2446	2072	1727	1439	1151
		72.09	0.500	2800	2380	2793	2366	1972	1643	1314
16	16	36.87	0.219	1080	918	1070	906	755	630	504
		42.05	0.250	1230	1046	1222	1035	863	719	575
		47.22	0.281	1380	1173	1374	1164	970	808	646
		52.36	0.312	1530	1301	1525	1292	1076	897	718
		57.48	0.344	1690	1437	1681	1424	1187	989	791
		62.58	0.375	1840	1564	1833	1552	1294	1078	862
		72.72	0.438	2150	1828	2141	1814	1511	1260	1008
		82.77	0.500	2450	2083	2444	2070	1725	1438	1150

WORKING PRESSURES OF PIPE

(Based on ASA Code B 31.8-1958)

Table 4, Page 2

API Standard 5LX-46 — Seamless, Electric Resistance Welded, Electric Flash Welded, and Submerged Arc Welded Pipe

(Specified Minimum Yield Strength — 46,000 psi)

Nominal Size (in.)	Outside Diameter (in.)	Weight (lb/ft)	Wall Thickness (in.)	Specified Mill Test Pressure (psi)	1 85% of Mill Test Pressure (psi)	2 Maximum Hydrostatic Test Pressure (psi)	3 Working Pressure, Type "A" Construction (psi)	4 Working Pressure, Type "B" Construction (psi)	5 Working Pressure, Type "C" Construction (psi)	6 Working Pressure, Type "D" Construction (psi)
18	18	47.39	0.250	1090	927	1086	920	767	639	511
		53.22	0.281	1230	1046	1221	1034	862	718	574
		59.03	0.312	1360	1156	1356	1148	957	788	638
		64.82	0.344	1500	1275	1494	1266	1055	879	703
		70.59	0.375	1630	1386	1629	1380	1150	959	767
		76.34	0.406	1770	1505	1764	1494	1245	1038	830
		82.06	0.438	1910	1624	1903	1612	1343	1120	896
		93.45	0.500	2180	1853	2173	1840	1534	1278	1022
20	20	52.73	0.250	980	833	978	828	690	575	460
		59.23	0.281	1100	935	1099	931	776	647	517
		65.71	0.312	1220	1037	1216	1030	858	715	572
		72.16	0.344	1350	1148	1345	1139	949	791	633
		78.60	0.375	1470	1250	1466	1242	1035	863	690
		85.01	0.406	1590	1352	1588	1345	1121	934	747
		91.41	0.438	1720	1462	1713	1451	1209	1008	806
		104.13	0.500	1960	1666	1955	1656	1380	1150	920
22	22	58.07	0.250	890	757	888	752	627	523	418
		65.24	0.281	1000	850	999	846	705	588	470
		72.38	0.312	1110	944	1109	940	783	653	522
		79.51	0.344	1230	1046	1223	1036	863	720	576
		86.61	0.375	1340	1139	1333	1129	941	784	627
		93.69	0.406	1450	1233	1443	1223	1019	849	679
		100.75	0.438	1560	1326	1557	1319	1099	916	733
		114.81	0.500	1780	1513	1777	1506	1255	1046	836
24	24	63.41	0.250	820	697	814	690	575	479	383
		71.25	0.281	920	782	915	775	646	539	431
		79.06	0.312	1020	867	1017	861	718	598	478
		86.85	0.344	1130	961	1121	950	791	660	528
		94.62	0.375	1230	1046	1222	1035	863	719	575
		102.37	0.406	1330	1131	1323	1120	934	778	622
		110.10	0.438	1430	1216	1427	1209	1007	840	671
		125.49	0.500	1630	1386	1629	1380	1150	959	767
26	26	68.75	0.250	760	646	751	636	530	442	354
		77.25	0.281	850	723	845	716	596	497	398
		85.73	0.312	940	799	938	795	662	552	442
		94.19	0.344	1040	884	1034	876	730	609	487
		102.63	0.375	1130	961	1128	955	796	664	531
		111.05	0.406	1230	1046	1221	1035	862	719	575
		119.44	0.438	1320	1122	1317	1115	929	775	620
		136.17	0.500	1510	1284	1504	1274	1061	885	708
28	28	74.09	0.250	700	595	698	591	493	411	328
		83.26	0.281	790	672	785	665	554	462	369
		92.41	0.312	880	748	871	738	615	513	410
		101.53	0.344	970	825	961	814	678	565	452
		110.64	0.375	1050	893	1047	887	739	616	493
		119.72	0.406	1140	969	1134	960	800	667	534
		128.79	0.438	1230	1046	1223	1036	863	720	576
		146.85	0.500	1400	1190	1397	1183	986	822	657
30	30	79.43	0.250	660	561	652	552	460	384	307
		89.27	0.281	740	629	733	621	517	431	345
		99.08	0.312	820	697	813	689	574	479	383
		108.88	0.344	900	765	897	760	633	528	422
		118.65	0.375	980	833	978	828	690	575	460
		128.40	0.406	1060	901	1058	896	747	623	498
		138.13	0.438	1150	978	1136	963	802	669	535
		157.53	0.500	1310	1114	1303	1104	920	767	613

WORKING PRESSURES OF PIPE

(Based on ASA Code B 31.8-1958)

Table 5

API Standard 5LX-52 — Seamless, Electric Resistance Welded, Electric Flash Welded, and Submerged Arc Welded Pipe

(Specified Minimum Yield Strength — 52,000 psi)

Nominal Size (in.)	Outside Diameter (in.)	Weight (lb/ft)	Wall Thickness (in.)	Specified Mill Test Pressure (psi)	1 85% of Mill Test Pressure (psi)	2 Maximum Hydrostatic Test Pressure (psi)	3 Working Pressure, Type "A" Construction (psi)	4 Working Pressure, Type "B" Construction (psi)	5 Working Pressure, Type "C" Construction (psi)	6 Working Pressure, Type "D" Construction (psi)
		12.89	0.188	2220	1887	2508	2125	1771	1476	1180
		14.97	0.219	2580	2193	2922	2475	2063	1719	1375
		17.02	0.250	2950	2508	3336	2826	2355	1963	1570
6	6.625	18.97	0.280	3000	2550	3736	3164	2637	2198	1758
		21.07	0.312	3000	2550	4163	3527	2939	2449	1959
		23.06	0.344	3000	2550	4590	3888	3240	2700	2160
		25.03	0.375	3000	2550	5004	4239	3532	2949	2355
		28.57	0.432	3000	2550	5765	4883	4069	3391	2713
		16.90	0.188	1710	1454	1927	1632	1360	1134	907
		18.27	0.203	1840	1564	2081	1763	1469	1224	979
		19.64	0.219	1990	1692	2245	1901	1585	1321	1056
		22.36	0.250	2270	1930	2562	2170	1808	1507	1206
		24.70	0.277	2510	2134	2839	2405	2004	1670	1336
8	8.625	27.74	0.312	2830	2406	3198	2709	2257	1881	1505
		28.55	0.322	2920	2482	3301	2796	2330	1947	1553
		30.40	0.344	3000	2550	3526	2987	2489	2074	1659
		33.04	0.375	3000	2550	3844	3256	2713	2261	1809
		38.26	0.438	3000	2550	4489	3802	3169	2641	2112
		43.39	0.500	3000	2550	5125	4341	3617	3015	2412
		21.15	0.188	1550	1318	1546	1310	1019	910	728
		22.88	0.203	1670	1420	1669	1414	1178	982	786
		24.60	0.219	1810	1539	1801	1526	1271	1060	848
		28.04	0.250	2060	1751	2056	1742	1451	1210	968
		31.20	0.279	2300	1955	2294	1943	1619	1350	1080
10	10.75	34.24	0.307	2530	2151	2525	2138	1782	1485	1188
		38.20	0.344	2830	2406	2829	2396	1997	1664	1331
		40.48	0.365	3000	2550	3001	2542	2119	1766	1412
		48.19	0.438	3000	2550	3601	3051	2542	2119	1695
		54.74	0.500	3000	2550	4111	3483	2902	2419	1935
		27.22	0.203	1410	1199	1408	1192	994	828	662
		29.28	0.219	1520	1292	1518	1286	1072	893	714
		33.38	0.250	1740	1479	1733	1468	1223	1020	816
		37.45	0.281	1950	1658	1948	1650	1375	1146	917
		41.51	0.312	2170	1845	2163	1832	1527	1273	1018
12	12.75	43.77	0.330	2290	1947	2288	1938	1615	1346	1077
		45.55	0.344	2390	2032	2385	2020	1684	1403	1122
		49.56	0.375	2600	2210	2599	2202	1835	1529	1223
		53.56	0.406	2820	2397	2815	2385	1987	1656	1325
		57.53	0.438	3000	2550	3037	2573	2144	1787	1429
		65.42	0.500	3000	2550	3466	2936	2447	2039	1631
		30.93	0.210	1330	1131	1326	1123	936	780	624
		32.20	0.219	1390	1182	1383	1171	976	814	650
		36.71	0.250	1580	1343	1578	1337	1114	929	743
		41.21	0.281	1780	1513	1774	1503	1252	1044	835
14	14	45.68	0.312	1980	1683	1970	1669	1391	1159	927
		50.14	0.344	2180	1853	2172	1840	1533	1278	1022
		54.57	0.375	2370	2015	2368	2006	1672	1393	1114
		63.37	0.438	2770	2355	2766	2343	1952	1627	1302
		72.09	0.500	3000	2550	3160	2674	2228	1857	1486
		36.87	0.219	1220	1037	1210	1025	854	712	570
		42.05	0.250	1390	1182	1381	1170	975	813	650
		47.22	0.281	1560	1326	1553	1315	1096	914	731
		52.36	0.312	1730	1471	1724	1460	1217	1014	811
16	16	57.48	0.344	1910	1624	1901	1610	1342	1118	894
		62.58	0.375	2080	1768	2071	1755	1462	1219	975
		72.72	0.438	2430	2066	2420	2050	1708	1424	1139
		82.77	0.500	2770	2355	2763	2340	1950	1625	1300

WORKING PRESSURES OF PIPE

(Based on ASA Code B 31.8-1958)

Table 5, Page 2

API Standard 5LX-52 —

Seamless, Electric Resistance Welded, Electric Flash Welded, and Submerged Arc Welded Pipe

(Specified Minimum Yield Strength — 52,000 psi)

Nominal Size (in.)	Outside Diameter (in.)	Weight (lb/ft)	Wall Thickness (in.)	Specified Mill Test Pressure (psi)	1 85% of Mill Test Pressure (psi)	2 Maximum Hydrostatic Test Pressure (psi)	3 Working Pressure, Type "A" Construction (psi)	4 Working Pressure, Type "B" Construction (psi)	5 Working Pressure, Type "C" Construction (psi)	6 Working Pressure, Type "D" Construction (psi)
		47.39	0.250	1230	1046	1227	1040	866	722	578
		53.22	0.281	1380	1173	1380	1169	974	812	650
		59.03	0.312	1540	1309	1533	1298	1081	902	721
18	18	64.82	0.344	1690	1437	1690	1431	1192	994	795
		70.59	0.375	1850	1573	1842	1560	1300	1084	867
		76.34	0.406	2000	1700	1994	1689	1408	1173	938
		82.06	0.438	2160	1836	2151	1822	1519	1266	1012
		93.45	0.500	2460	2091	2456	2080	1733	1445	1156
		52.73	0.250	1110	944	1105	936	780	650	520
		59.23	0.281	1250	1063	1242	1052	877	732	584
		65.71	0.312	1380	1173	1379	1168	973	811	649
20	20	72.16	0.344	1530	1301	1521	1288	1073	895	716
		78.60	0.375	1660	1411	1658	1404	1170	975	780
		85.01	0.406	1800	1530	1794	1520	1267	1051	844
		91.41	0.438	1940	1649	1936	1640	1367	1139	911
		104.13	0.500	2220	1887	2210	1872	1560	1300	1040
		58.07	0.250	1010	859	1005	851	709	591	473
		65.24	0.281	1130	961	1129	956	797	664	531
		72.38	0.312	1260	1071	1254	1062	885	738	590
22	22	79.51	0.344	1390	1182	1382	1171	976	813	650
		86.61	0.375	1510	1284	1507	1277	1064	887	709
		93.69	0.406	1640	1394	1631	1382	1151	960	768
		100.75	0.438	1770	1505	1760	1491	1243	1036	828
		114.81	0.500	2010	1709	2009	1702	1418	1182	946
		63.41	0.250	930	791	921	780	650	542	433
		71.25	0.281	1040	884	1035	877	731	609	487
		79.06	0.312	1150	978	1149	973	811	676	541
24	24	86.85	0.344	1270	1080	1267	1074	895	746	596
		94.62	0.375	1390	1182	1381	1170	975	813	650
		102.37	0.406	1500	1275	1495	1266	1055	875	704
		110.10	0.438	1620	1377	1613	1367	1139	949	759
		125.49	0.500	1850	1573	1842	1560	1300	1084	867
		68.75	0.250	860	731	850	720	600	500	400
		77.25	0.281	960	816	955	809	674	562	450
		85.73	0.312	1070	910	1061	899	749	624	499
26	26	94.19	0.344	1170	995	1170	991	826	688	550
		102.63	0.375	1280	1088	1275	1080	900	750	600
		111.05	0.406	1390	1182	1380	1169	974	812	650
		119.44	0.438	1490	1267	1489	1261	1051	876	701
		136.17	0.500	1700	1445	1700	1440	1200	1000	800
		74.09	0.250	790	672	790	669	557	465	372
		83.26	0.281	890	757	887	752	626	522	418
		92.41	0.312	990	842	985	834	695	580	464
28	28	101.53	0.344	1090	927	1086	920	767	639	511
		110.64	0.375	1190	1012	1184	1003	836	697	557
		119.72	0.406	1290	1097	1282	1086	905	754	603
		128.79	0.438	1390	1182	1383	1171	976	814	651
		146.85	0.500	1580	1343	1578	1337	1114	929	743
		79.43	0.250	740	629	737	624	520	434	347
		89.27	0.281	830	706	805	701	584	487	390
		99.08	0.312	920	782	920	779	649	541	433
		108.88	0.344	1020	867	1014	859	716	597	477
30	30	118.65	0.375	1110	944	1105	936	780	650	520
		128.40	0.406	1200	1020	1196	1013	844	704	563
		138.13	0.438	1300	1105	1290	1086	911	759	607
		157.53	0.500	1480	1258	1473	1248	1040	867	693

Visual Identification of Line Pipe

Often during the course of his work it is necessary for the engineer in the field to identify specific kinds of pipe as to their method of manufacture. Although it would require a complete laboratory examination to positively identify a specimen of pipe as to its specific API or ASTM specifications, various kinds of line pipe have characteristics that enable them to be readily identified by visual examination when mill stenciling or other identification has been lost.

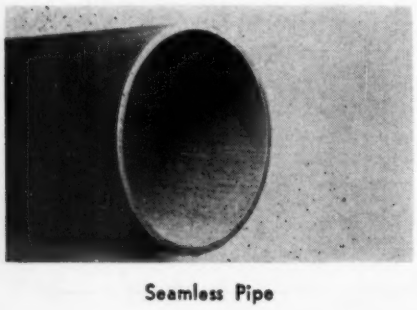
Line pipe generally can be classified into five groups related to method of manufacture. These five common pipe fabricating processes produce pipe that can be classified as follows: **Seamless, electric resistance welded, electric fusion welded, lap welded, and butt welded.** In general, it can be said that, although all imperfections are not injurious, pipe can be identified most easily through defects occurring during fabrication.

Seamless Pipe

Seamless, as the class name implies, has no welded seam; it is produced by spinning and pushing a heated billet over a stationary piercing mandrel. By this process, it is theoretically possible to manufacture a tube of uniform wall thickness, roundness and surface finish. One imperfection or a combination of slight imperfections, however, produced into the pipe during fabrication serve positively to identify seamless pipe. Longitudinal spiraling internal mandrel scores in varying degrees of depth and quantity are found. Another defect appears as spiraling folds, called "seams," found on either surface for any length along a joint of pipe. A third characteristic of seamless pipe may be non-uniform wall thickness that results when the inside diameter is not concentric with the outside diameter. The thick portion of the wall will always be diametrically opposite the thin portion.

Identifying characteristics:

1. *Absence of a welded seam;*
2. *Longitudinal spiraling internal mandrel scores;*
3. *Spiraling internal or external folds (seams);*
4. *Eccentricity of ID to OD.*



Seamless Pipe

Electric Resistance Welded Pipe (Flash)

Electric Resistance Welded Pipe

Electric resistance welded pipe is cold formed from long lengths of hot rolled sheet, called skelp, and then welded under pressure by heat from electric resistance without the addition of a filler metal. Two types come under this classification, each having its own characteristics. One type of resistance welded pipe is formed into a tube in progressive pressing operations and welded instantaneously by a flash welding process. Principal indentifying characteristic of this product is the resulting upset weld. After welding, the flash is machined, leaving a keyed upset 1/32 to 1/16-in. high by ¼ to ½-in. wide on both internal and external surfaces.

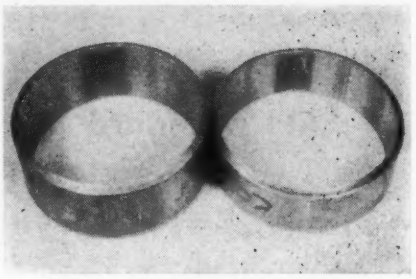
Identifying characteristics:

1. *Uniform wall thickness;*
2. *Smooth internal and external surfaces;*
3. *Flat key upset on both weld surfaces.*

A second type of resistance welded pipe is formed on a series of forming rolls and electric resistance welded under stationary rolling electrodes as the pipe moves down the mill. The weld flash thus produced is completely trimmed off on both surfaces while still hot to produce contoured surfaces flush with the contour of the pipe wall. Several irregularities found in the weld zone distinguish this type of manufacture. When new, the weld zone shows a characteristic metallic blue color where it has been heated. A worn electrode can cause a path of slight feathered electrode burns in the metal along both sides of the weld. Also, the internal flash trimmer cannot be controlled as easily as the external trimmer and may leave either a slight upset band at the weld, or gouge a shallow undercut at the internal surface of the weld.

Identifying characteristics:

1. *Uniform wall thickness;*
2. *Smooth internal and external surfaces;*
3. *Slight upset or undercutting at internal weld surface;*
4. *Electrode feather burns along external weld zone.*



Electric Resistance Welded Pipe (Continuous)

Electric Fusion Welded Pipe

Although there are several types in this classification, all are electric welded with the addition of a filler metal. The weld can be made manually, the practice at small shops, or it can be made continuously with automatic equipment. The tube may be formed with a longitudinal weld seam, or it may be formed spirally. All types exhibit the typical weld bead of filler metal.

Identifying characteristics:

1. *Uniform wall thickness;*
2. *Smooth internal and external surfaces;*
3. *Prominent fusion weld bead present.*

Lap Welded Pipe

Lap welded pipe is made by heating the entire skelp and then forcing it over a mandrel with a pair of rolls embossed with a herringbone or knurled pattern. The pressure of the welding rolls completes a lap weld and also impresses a most distinctive herringbone or knurled pattern into the external surfaces of the pipe. Longitudinal scratches caused by the mandrel often can be found on internal surfaces and the lapped edge of the weld often can be seen on either surface as an irregular line, especially after a period of use under corrosive attack.

Identifying characteristics:

1. *Prominent external herringbone or knurled pattern;*
2. *Internal longitudinal scratches;*
3. *Lap weld sometimes visible as irregular line on either surface.*

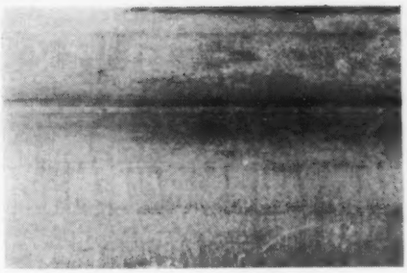
Butt Welded Pipe

Butt welded pipe has been made in sizes not exceeding 4½-in. OD by two different processes, loosely called "furnace welded" and "continuous welded." In furnace welded pipe, skelp

with square cut or slightly beveled edges is heated to welding temperature in a furnace and then drawn through a funnel shaped die or through welding rolls into tubular form with sufficient edge pressure to make a welded seam.

Continuous welded pipe is the product of a more modern method of butt welding in that the skelp is drawn through a furnace from endless coils, the end of one coil being machine flash welded to the leading end of a new coil. The pipes produced by both methods are difficult to distinguish from each other and either can be confused easily with seamless, unless carefully inspected.

Characteristic defects are few and not very pronounced when they do occur. Both types are smooth internally and externally with occasional external longitudinal scratches or feathered scratches adjacent to the weld. The straight weld usually can be seen down the length of the pipe on either surface varying from an almost invisible hairline to a prominent V-shaped notch.

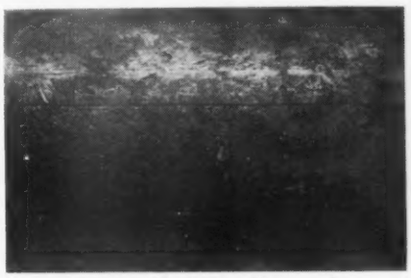


Electric Fusion Welded Pipe

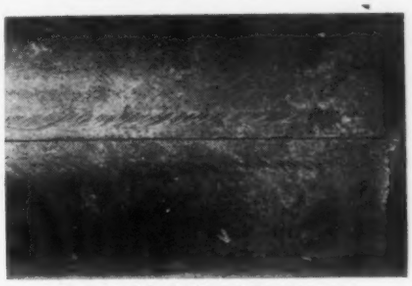
Lap Welded Pipe

Identifying characteristics:

1. *Smooth internal and external surfaces;*
2. *Longitudinal or feathered scratches adjacent to external weld;*
3. *Visible straight line weld internally or externally.*



Butt Welded Pipe (Furnace)



Butt Welded Pipe (Continuous)

Lowest Recorded Temperatures and Annual Degree Days for U. S. and Canadian Cities

DEGREE DAYS is a term used to express the intensity of the heating season. It is the difference between 65 F. and the daily mean temperature. The sum of these differences for every day of the heating season is the total degree days for the year. Experience has shown that the gas heating season starts when the monthly mean temperature is 65 F., and that gas consumption for house heating is proportional to the drop in temperature below 65 F.

City	Min. Temp.	Degree-Days
Alabama		
Montgomery	— 5	1886
Tuscaloosa	— 7	2529
Arizona		
Flagstaff	—25	7145
Tucson	6	1845
Arkansas		
Little Rock	—12	2811
Texarkana	— 7	2216
California		
Los Angeles	28	1504
Sacramento	19	2654
San Francisco	29	3264
Colorado		
Colorado Springs	—27	6553
Denver	—29	5873
Connecticut		
Hartford	—18	6037
New Haven	—14	5895
Delaware		
Wilmington	—12	4788
District of Columbia		
Washington	—15	4626
Florida		
Monticello	16	1129
Tampa	9	296
Georgia		
Atlanta	— 8	2891
Macon	— 4	2203
Savannah	8	1490
Idaho		
Boise	—28	4558
Springfield	—28	7477
Illinois		
Chicago	—23	6315
Springfield	—24	5370
Indiana		
Evansville	—16	4164
Indianapolis	—25	5297
South Bend	—20	6076
Iowa		
Des Moines	—30	6373
Sioux City	—35	7023
Kansas		
Topeka	—25	5301
Wichita	—22	4877
Kentucky		
Lexington	—20	4616
Louisville	—20	4180
Louisiana		
New Orleans	7	1023
Shreveport	— 5	1938
Maine		
Bar Harbor	—21	7643
Portland	—21	7012
Maryland		
Baltimore	— 7	4333
Massachusetts		
Boston	—14	6145
Williamstown	—26	7221
Michigan		
Cadillac	—36	7967
Detroit	—28	6494
Grand Rapids	—24	6534
Sault Ste. Marie	—37	9281
Minnesota		
Duluth	—41	9480
Minneapolis	—33	7851
Rochester	—42	8123
Mississippi		
Corinth	— 8	3411
Vicksburg	— 1	1809
Missouri		
Kansas City	—22	5202
St. Louis	—22	4585
Montana		
Billings	—49	7115
Butte	—33	8271
Nebraska		
Dumas	—31	7203
Omaha	—32	6128
Nevada		
Las Vegas	8	2842
Reno	—19	5891
New Hampshire		
Concord	—35	6852
Hanover	—37	8063
New Jersey		
Atlantic City	— 7	5175
Trenton	—13	4934
New Mexico		
Albuquerque	—10	4303
Santa Fe	—13	6063
New York		
Albany	—24	6889
Buffalo	—14	6821
New York City	—13	5348
Saranac Lake	—39	8673
North Carolina		
Greensboro	— 3	3527
Wilmington	5	2302
North Dakota		
Bismarck	—45	8494
Hannah	—54	10714
Ohio		
Cincinnati	—17	4702
Cleveland	—17	6154
Columbus	—20	5323
Oklahoma		
Oklahoma City	—17	3613
Tulsa	—15	3560
Oregon		
Portland	— 2	4468
Wallowa	—38	7360
Pennsylvania		
Philadelphia	— 6	4855
Pittsburgh	—20	5235
Scranton	—15	6129
Rhode Island		
Providence	—12	6014
South Carolina		
Charleston	7	1769
Spartanburg	— 4	3257
South Dakota		
Aberdeen	—46	8709
Jefferson	—48	8419
Tennessee		
Knoxville	—16	3670
Memphis	— 9	2950
Nashville	—13	3578
Texas		
Dallas	—10	2455
Galveston	8	1016
San Antonio	4	1202
Utah		
Provo	—23	6184
Salt Lake City	—20	5553
Vermont		
Burlington	—28	7620
Northfield	—41	8420
Virginia		
Fredericksburg	—21	4243
Richmond	— 3	3725
Washington		
Seattle	3	4868
Spokane	—30	6353
West Virginia		
Charleston	—17	3786
Wisconsin		
Milwaukee	—25	7372
Superior	—35	9750
Wyoming		
Casper	—30	6979
Cheyenne	—38	7462
Canada		
Vancouver, B. C.		5976
Winnipeg, Man.		11166
Toronto, Ont.		7732
Montreal, Que.		8705

From AGA "Househeating" and U. S. Weather Bureau.

Flange Matching

One of the problems frequently facing engineers in the gas utility operations is determining what flange to use with a certain type of valve. Valves are made in a variety of types with an equally large number of standard specifications. Valves commonly used in gas distribution operations range from 125-lb. working pressure up to 2500-lb. working pressure. In this range, there are at least 11 different flange dimension standards. Some flanges are interchangeable, some are not.

Matching flange dimensions of valves with available flange fittings can often be a frustrating experience for even the most seasoned engineer.

Use of the tables on **"Flange Data,"** in this *Gas Handbook Issue* can help simplify the problem.

Example: A 3-in. 500-lb WOG valve furnished with 250-lb cast iron raised face flanges is to be installed. *What ASA steel flange should be specified to match this valve?*

Checking the tables, beginning with *"Diameter of Bolt Circle —Inches,"* it can be found that there are six different types of flanges that may be considered — 250-lb cast iron, ASA 300-lb, 500-lb working pressure, ASA 400-lb, ASA 600-lb, and 800-lb hydraulic cast iron.

Moving to the second table, *"Number and Diameter of Stud Bolts,"* it can also be found that the same six types of flanges can be considered.

Moving to the third table, *"Flange Diameter — Inches,"* again the same six types will match and can be considered.

In the fourth table, *"Flange Thickness — Inches,"* the choice is narrowed. Only two flange specifications match — the 250-lb cast iron and the ASA 300-lb raised face flange. Both have a thickness of 1⅛-in. **If matching flanges are desired, then only the ASA 300-lb flanges should be specified to match the valve flanges.**

To make the selection task somewhat simpler, AMERICAN GAS JOURNAL has prepared the following "Flange Matching Tables," which provide data on various types of semi-steel plug valves and their matching flanges.

The tables can also be used for other types of valves if the flange specifications of the valve are known. (This can be obtained from manufacturers' catalogs.) For example, if the valve is furnished with 125-lb cast iron flanges, refer to the first table to find the matching flange. If the valve is furnished with 250-lb cast iron raised face flanges, refer to the second table.

Flange Matching Table for Semi-Steel Plug Valves

VALVES: 175-lb WOG 350-lb Test; 200-lb WOG 400-lb Test (Note 1); 120-lb WOG 240-lb Test — **FLANGES:** ASA 150-lb Flat Face or 125-lb (175-lb WOG) Lt. Wt. Taper Face (Note 4) or 125-lb Cast Iron

	1	1¼	1½	2	2½	3	4	6	8	10	12	14	16	18	20
Bolt Circle Diameter	3⅛	3½	3⅞	4¾	5½	6	7½	9½	11¾	14¼	17	18¾	21¼	22¾	25
Number of Bolts	4	4	4	4	4	4	8	8	8	12	12	12	16	16	20
Bolt Diameter	½	½	½	⅝	⅝	⅝	⅝	¾	¾	⅞	⅞	1	1	1⅛	1⅛
Bolt Length	2	2¼	2¼	2½	2¾	3	3	3¼	3½	3¾	3¾	4¼	4¾	4¾	5
Flange Diameter	4¼	4⅝	5	6	7	7½	9	11	13½	16	19	21	23½	25	27½
Flange Thickness, ASA	9/16	5/8	11/16	¾	⅞	15/16	15/16	1	1⅛	1 3/16	1¼	1⅜	1 7/16	1 9/16	1 11/16
Flange Thickness, C.I.	7/16	½	9/16	⅝	11/16	¾	15/16	1	1⅛	1 3/16	1¼	1⅜	1 7/16	1 9/16	1 11/16

VALVES: 400-lb WOG 800-lb Test (Note 2); 500-lb WOG 1000-lb Test (Note 3) — **FLANGES:** ASA 300-lb Raised Face; 250-lb Cast Iron Raised Face

	1	1¼	1½	2	2½	3	4	6	8	10	12	14	16	18	20
Bolt Circle Diameter	3½	3⅞	4½	5	5⅞	6⅝	7⅞	10⅝	13	15¼	17¾	20¼	22½	24¾	27
Number of Bolts	4	4	4	8	8	8	8	12	12	16	16	20	20	24	24
Bolt Diameter	⅝	⅝	¾	⅝	¾	¾	¾	¾	⅞	1	1⅛	1⅛	1¼	1¼	1¼
Bolt Length, Stud Bolts	3¼	3½	3¾	3¾	4¼	4½	4¾	5	5¾	6½	7	7¼	8	8¼	8¾
Machine Bolt Length	2½	2½	2¾	3	3½	3¾	4	4¼	4¾	5½	5¾	6½	6¾	7	7¼
Flange Diameter	4⅞	5¼	6⅛	6½	7½	8¼	10	12½	15	17½	20½	23	25½	28	30½
Flange Thickness	11/16	¾	13/16	⅞	1	1⅛	1¼	1 7/16	1⅝	1⅞	2	2⅛	2¼	2⅜	2½
Diam. of 1/16-in. ASA R.F.	2	2½	2⅞	3½	4⅛	5	6 3/16	8½	10⅞	12¾	15	16¼	18½	21	23
Diam. of 1/16-in. C.I. R.F.	2 11/16	3 1/16	3 9/16	4 3/16	4 15/16	5 11/16	6 15/16	9 11/16	11 15/16	14 1/16	16 7/16	18 15/16	21 1/16	23 5/16	25 9/16

VALVES: 800-lb WOG 1600-lb Test **FLANGES:** ASA 600-lb Raised Face (Note 5)

	2	2½	3	4	6	8	10	12
Bolt Circle Diameter	5	5⅞	6⅝	8½	11½	13¾	17	19¼
Number of Bolts	8	8	8	8	12	12	16	20
Bolt Diameter	⅝	¾	¾	⅞	1	1⅛	1¼	1¼
Bolt Length, Stud Bolts	4½	5	5¼	6	7	7¾	8¾	9
Flange Diameter	6½	7½	8¼	10¾	14	16½	20	22
Flange Thickness, ASA 600-lb	1	1⅛	1¼	1½	1⅞	2 3/16	2½	2⅞
Flange Thickness, 800-lb Hyd. C.I.	1¼	1⅜	1½	1⅞	2¼	2½	2⅞	3

NOTES: In some cases Cap Screws or Bolt-Studs are necessary. When this is true, the number of Cap Screws required is subtracted from the number of bolts given in the table to determine the total bolting.

Semi-steel valve type	NOTE 1: 200-lb WOG 400-lb Test short pattern				NOTE 2: 400-lb WOG 800-lb test short pattern			NOTE 3: 500-lb WOG 1000-lb test Venturi pattern
Size	6	8	10	12	2	2½	3	12
No. of Cap Screws or Bolt-Studs	2	2	2	2	4	4	2	2
Cap Screw Length	2	2¼	2½	2½	2	2¼	2½	3¾
Bolt-Stud Length	3	3¼	3½	3¾	2¾	3¼	3½	5¼

NOTE 4: The 125-lb light weight taper face flange has same maximum service pressure rating as the Class 125 cast iron or "semi-steel" valve.

NOTE 5: Except for flange thickness and length of bolts required, the 800-lb Hydraulic Cast Iron flange has same dimensions as the ASA 600-lb Steel flange. Customary practice is to use the ASA 600-lb flange instead of the 800-lb Hydraulic C. I. flange.

ACKNOWLEDGMENT: *The flange matching tables presented here are based in part on data in "Flange Matching Tables," published and copyrighted by Tube Turns, Division of Chemetron Corporation, and reproduced by permission.*

Flange Data

DIAMETER OF BOLT CIRCLE — INCHES

Flange Size	125# C.I.	ASA 150	250# C.I.	ASA 300	500# W.P.	ASA 400	ASA 600	800# HYD.	ASA 900	ASA 1500	ASA 2500
2	4-3/4	4-3/4	5	5	5	5	5	5	6-1/2	6-1/2	6-3/4
2-1/2	5-1/2	5-1/2	5-7/8	5-7/8	5-7/8	5-7/8	5-7/8	5-7/8	7-1/2	7-1/2	7-3/4
3	6	6	6-5/8	6-5/8	6-5/8	6-5/8	6-5/8	6-5/8	7-1/2	8	9
4	7-1/2	7-1/2	7-7/8	7-7/8	7-7/8	7-7/8	8-1/2	8-1/2	9-1/4	9-1/2	10-3/4
6	9-1/2	9-1/2	10-5/8	10-5/8	10-5/8	10-5/8	11-1/2	11-1/2	12-1/2	12-1/2	14-1/2
8	11-3/4	11-3/4	13	13	13	13	13-3/4	13-3/4	15-1/2	15-1/2	17-1/4
10	14-1/4	14-1/4	15-1/4	15-1/4	15-1/4	15-1/4	17	17	18-1/2	19	21-1/4
12	17	17	17-3/4	17-3/4	17-3/4	17-3/4	18-1/4	19-1/4	21	22-1/2	24-3/8
14	18-3/4	18-3/4	20-1/4	20-1/4	20-1/4	20-1/4	20-3/4	—	22	25	—
16	21-1/4	21-1/4	22-1/2	22-1/2	22-1/2	22-1/2	23-3/4	—	24-1/4	27-3/4	—
18	22-3/4	22-3/4	24-3/4	24-3/4	24-3/4	24-3/4	25-3/4	—	27	30-1/2	—
20	25	25	27	27	27	27	28-1/2	—	29-1/2	32-3/4	—
22	—	27-1/4	—	—	—	—	—	—	—	—	—
24	29-1/2	29-1/2	32	32	32	32	—	—	35-1/2	39	—
26	—	—	—	—	—	—	—	—	—	—	—
30	36	—	—	—	—	—	—	—	—	—	—

NUMBER AND DIAMETER OF STUD BOLTS

Flange Size	125# C.I. No.	Diam.	ASA 150 No.	Diam.	250# C.I. No.	Diam.	ASA 300 No.	Diam.	500# W.P. No.	Diam.	ASA 400 No.	Diam.	ASA 600 No.	Diam.	800# HYD. No.	Diam.	ASA 900 No.	Diam.	ASA 1500 No.	Diam.	ASA 2500 No.	Diam.
2	4	-5/8	4	-5/8	8	-5/8	8	-5/8	8	-5/8	8	-5/8	8	-5/8	8	-5/8	8	-7/8	8	-7/8	8	1
2-1/2	4	-5/8	4	-5/8	8	-3/4	8	-3/4	8	-3/4	8	-3/4	8	-3/4	8	-3/4	8	1	8	1	8	1-1/16
3	4	-5/8	4	-5/8	8	-3/4	8	-3/4	8	-3/4	8	-3/4	8	-3/4	8	-3/4	8	-7/8	8	1-1/8	8	1-1/4
4	8	-5/8	8	-5/8	8	-3/4	8	-3/4	8	-3/4	8	-7/8	8	-7/8	8	-7/8	8	1-1/8	8	1-1/4	8	1-1/2
6	8	-3/4	8	-3/4	12	-3/4	12	-3/4	12	-3/4	12	-7/8	12	1	12	1	12	1-1/8	12	1-3/8	8	2
8	8	-3/4	8	-3/4	12	-7/8	12	-7/8	12	-7/8	12	1	12	1-1/8	12	1-1/8	12	1-3/8	12	1-5/8	12	2
10	12	-7/8	12	-7/8	16	1	16	1	16	1	16	1-1/8	16	1-1/4	16	1-1/4	16	1-3/8	12	1-7/8	12	2-1/2
12	12	-7/8	12	-7/8	16	1-1/8	16	1-1/8	16	1-1/8	16	1-1/4	20	1-1/4	20	1-1/4	20	1-3/8	16	2	12	2-3/4
14	12	1	12	1	20	1-1/8	20	1-1/8	20	1-1/8	20	1-1/4	20	1-3/8	—	—	20	1-1/2	16	2-1/4	—	—
16	16	1	16	1	20	1-1/4	20	1-1/4	20	1-1/4	20	1-3/8	20	1-1/2	—	—	20	1-5/8	16	2-1/2	—	—
18	16	1-1/8	16	1-1/8	24	1-1/4	24	1-1/4	24	1-1/4	24	1-3/8	20	1-5/8	—	—	20	1-7/8	16	2-3/4	—	—
20	20	1-1/8	20	1-1/8	24	1-1/4	24	1-1/4	24	1-1/4	24	1-1/2	24	1-1/2	—	—	20	2	16	3	—	—
22	—		20	1-1/4	—		24	1-1/4	24	1-1/2	24	1-5/8	—	—	—	—	—	—	—	—	—	—
24	20	1-1/4	20	1-1/4	24	1-1/2	24	1-1/2	24	1-1/2	24	1-3/4	24	1-7/8	—	—	20	2-1/2	16	3-1/2	—	—
26	—		—		—		28	1-5/8	28	1-5/8	—		—		—	—	—	—	—	—	—	—
30	28	1-1/4	—		—		—		—		—		—		—	—	—	—	—	—	—	—

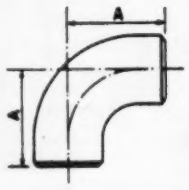
FLANGE DIAMETER — INCHES

Flange Size	125# C.I.	ASA 150	250# C.I.	ASA 300	500# W.P.	ASA 400	ASA 600	800# HYD.	ASA 900	ASA 1500	ASA 2500
2	6	6	6-1/2	6-1/2	6-1/2	6-1/2	6-1/2	6-1/2	8-1/2	8-1/2	9-1/4
2-1/2	7	7	7-1/2	7-1/2	7-1/2	7-1/2	7-1/2	7-1/2	9-5/8	9-5/8	10-1/2
3	7-1/2	7-1/2	8-1/4	8-1/4	8-1/4	8-1/4	8-1/4	8-1/4	9-1/2	10-1/2	12
4	9	9	10	10	10	10	10-3/4	10-3/4	11-1/2	12-1/4	14
6	11	11	12-1/2	12-1/2	12-1/2	12-1/2	14	14	15	15-1/2	19
8	13-1/2	13-1/2	15	15	15	15	16-1/2	16-1/2	18-1/2	19	21-3/4
10	16	16	17-1/2	17-1/2	17-1/2	17-1/2	20	20	21-1/2	23	26-1/2
12	19	19	20-1/2	20-1/2	20-1/2	20-1/2	22	22	24	26-1/2	30
14	21	21	23	23	23	23	23-3/4	—	25-1/4	29-1/2	—
16	23-1/2	23-1/2	25-1/2	25-1/2	25-1/2	25-1/2	27	—	27-3/4	32-1/2	—
18	25	25	28	28	28	28	29-1/4	—	31	36	—
20	27-1/2	27-1/2	30-1/2	30-1/2	30-1/2	30-1/2	32	—	33-3/4	38-3/4	—
22	—	29-1/2	—	33	33	33	—	—	—	—	—
24	32	32	36	36	36	36	37	—	41	46	—
26	—	—	—	33-1/4	33-1/4	—	—	—	—	—	—
30	38-3/4	—	—	—	—	—	—	—	—	—	—

FLANGE THICKNESS — INCHES

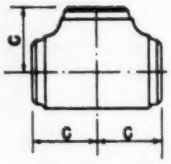
Size	125# C.I. R.F.	ASA 150 R.F.	ASA 150 R.J.	250# C.I. R.F.	ASA 300 R.F	ASA 300 R.J.	500# W.P. R.F.	ASA 400 R.F.	ASA 400 R.J	ASA 600 R.F.	ASA 600 R.J.	800# HYD. R.F.	ASA 900 R.F.	ASA 900 R.J.	ASA 1500 R.F.	ASA 1500 R.J.	ASA 2500 R.F.	ASA 2500 R.J.
2	5/8	3/4	1	7/8	7/8	1-3/16	1-1/16	1-1/4	1-5/16	1-1/4	1-5/16	1-1/2	1-3/4	1-13/16	1-3/4	1-13/16	2-1/4	2-5/16
2-1/2	11/16	7/8	1-1/8	1	1	1-5/16	1-3/16	1-3/8	1-7/16	1-3/8	1-7/16	1-5/8	1-7/8	1-15/16	1-7/8	1-15/16	2-1/2	2-5/8
3	3/4	15/16	1-3/16	1-1/8	1-1/8	1-7/16	1-5/16	1-1/2	1-9/16	1-1/2	1-9/16	1-3/4	1-3/4	1-13/16	2-1/8	2-3/16	2-7/8	3
4	15/16	15/16	1-3/16	1-1/4	1-1/4	1-9/16	1-1/2	1-5/8	1-11/16	1-3/4	1-13/16	2-1/8	2	2-1/16	2-3/8	2-7/16	3-1/4	3-7/16
6	1	1	1-1/4	1-7/16	1-7/16	1-3/4	1-11/16	1-7/8	1-15/16	2-1/8	2-3/16	2-1/2	2-7/16	2-1/2	3-1/2	3-5/8	4-1/2	4-3/4
8	1-1/8	1-1/8	1-3/8	1-5/8	1-5/8	1-15/16	1-15/16	2-1/8	2-3/16	2-7/16	2-1/2	2-3/4	2-3/4	2-13/16	3-7/8	4-1/16	5-1/4	5-9/16
10	1-3/16	1-3/16	1-7/16	1-7/8	1-7/8	2-3/16	2-3/16	2-3/8	2-7/16	2-3/4	2-13/16	3-1/8	3	3-1/16	4-1/2	4-11/16	6-3/4	7-3/16
12	1-1/4	1-1/4	1-1/2	2	2	2-5/16	2-5/16	2-1/2	2-9/16	2-7/8	2-15/16	3-1/4	3-3/8	3-7/16	5-1/8	5-7/16	7-1/2	7-15/16
14	1-3/8	1-3/8	1-5/8	2-1/8	2-1/8	2-7/16	2-1/2	2-5/8	2-11/16	3	3-1/16	3-1/2	3-5/8	3-13/16	5-1/2	5-7/8	—	—
16	1-7/16	1-7/16	1-1/16	2-1/4	2-1/4	2-9/16	2-5/8	2-3/4	2-13/16	3-1/4	3-5/16	3-3/4	3-3/4	3-15/16	6	6-7/16	—	—
18	1-9/16	1-9/16	1-13/16	2-3/8	2-3/8	2-11/16	2-3/4	2-7/8	2-15/16	3-1/2	3-9/16	4	4-1/4	4-1/2	6-5/8	7-1/16	—	—
20	1-11/16	1-11/16	1-15/16	2-1/2	2-1/2	2-7/8	2-7/8	3	3-1/8	3-3/4	3-7/8	4-1/4	4-1/2	4-3/4	7-1/4	7-11/16	—	—
22	1-13/16	1-13/16	2-1/16	2-5/8	2-5/8	—	3-1/8	3-1/8	—	—	—	—	—	—	—	—	—	—
24	1-7/8	1-7/8	2-1/8	2-3/4	2-3/4	3-3/16	3-3/16	3-1/4	3-7/16	4-1/4	4-7/16	5-1/4	5-3/4	6-1/8	8-1/4	8-13/16	—	—
26	—	—	—	2-13/16	2-13/16	—	3-5/16	—	—	—	—	—	—	—	—	—	—	—
30	2-1/8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Welding Fittings Data

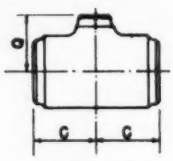


90° ELBOW

45° ELBOW

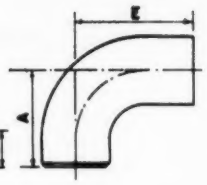


STRAIGHT TEE

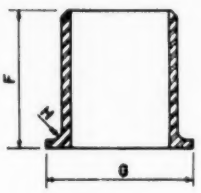


REDUCING TEE

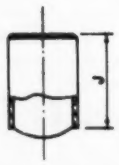
CAP



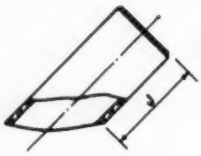
90° ELBOW WITH LONG TANGENT



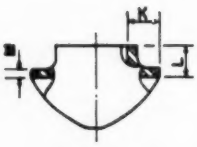
CRANELAP NIPPLE



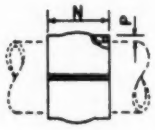
SHAPED NIPPLE 90° TO HEADER



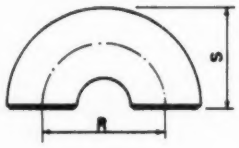
SHAPED NIPPLE 45° TO HEADER



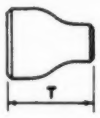
REINFORCING SADDLE



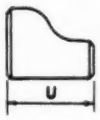
SLEEVE



RETURN BEND



CONCENTRIC REDUCER



ECCENTRIC REDUCER

ELBOWS, STRAIGHT TEES CAPS, NIPPLES, SADDLES, AND SLEEVES

Size	A	B	C	D	E	F	G	H	J	K	L	M	N	P
3/4	1-1/8	—	—	—	—	—	—	—	—	—	—	—	—	—
1	1-1/2	7/8	1-1/2	1-1/2	—	4	2	1/8	—	—	—	—	—	—
1-1/4	1-7/8	1	1-7/8	1-1/2	—	4	2-1/2	3/16	6	—	—	—	—	—
1-1/2	2-1/4	1-1/8	2-1/4	1-1/2	—	4	2-7/8	1/4	6	—	—	—	—	—
2	3	1-3/8	2-1/2	1-1/2	4-1/4	6	3-5/8	5/16	6	1-3/4	1-1/4	1/2	3	1/4
2-1/2	3-3/4	1-3/4	3	1-1/2	5	6	4-1/8	5/16	6	1-3/4	1-1/2	1/2	3	1/4
3	4-1/2	2	3-3/8	2	5-3/4	6	5	3/8	6	2	1-3/4	1/2	3	3/8
3-1/2	5-1/4	2-1/4	3-3/4	2-1/2	6-3/4	6	5-1/2	3/8	6	2	1-3/4	1/2	3-1/2	3/8
4	6	2-1/2	4-1/8	2-1/2	7-1/2	6	6-3/16	7/16	6	2	2	1/2	4	3/8
5	7-1/2	3-1/8	4-7/8	3	9	8	7-5/16	7/16	8	2	2	1/2	5	3/8
6	9	3-3/4	5-5/8	3-1/2	10-3/4	8	8-1/2	1/2	8	2-1/2	2-1/4	1/2	6	3/8
8	12	5	7	4	13-3/4	8	10-5/8	1/2	8	3	3	5/8	8	1/2
10	15	6-1/4	8-1/2	5	17	10	12-3/4	1/2	10	3-1/2	3-1/2	5/8	10	1/2
12	18	7-1/2	10	6	20-1/2	10	15	1/2	10	4	4	5/8	12	1/2
14 OD	21	8-3/4	11	6-1/2	—	12	16-1/4	1/2	—	4	4	5/8	14	1/2
16 OD	24	10	12	7	—	12	18-1/2	1/2	—	4	4	5/8	16	1/2
18 OD	27	11-1/4	13-1/2	8	—	12	21	1/2	—	4	4	5/8	18	1/2
20 OD	30	12-1/2	15	9	—	12	23	1/2	—	5	5	5/8	20	1/2
24 OD	36	15	17	10-1/2	—	12	27-1/4	1/2	—	5	5	5/8	24	1/2
30 OD	45	18-5/8	—	—	—	—	—	—	—	—	—	—	—	—

RETURN BENDS

Size of pipe	R	S
1	3	2-3/16
1-1/4	2-1/2	2-5/16
1-1/4	3-3/4	2-3/4
1-1/2	3	2-11/16
1-1/2	4-1/2	3-1/4
2	4	3-7/16
2	6	4-3/16
2-1/2	7-1/2	5-3/16
3	6	5
3	9	6-1/4
3-1/2	10-1/2	7-/14
4	8	6-1/2
4	12	8-1/4
5	15	10-5/16
6	18	12-5 16

REDUCING TEES

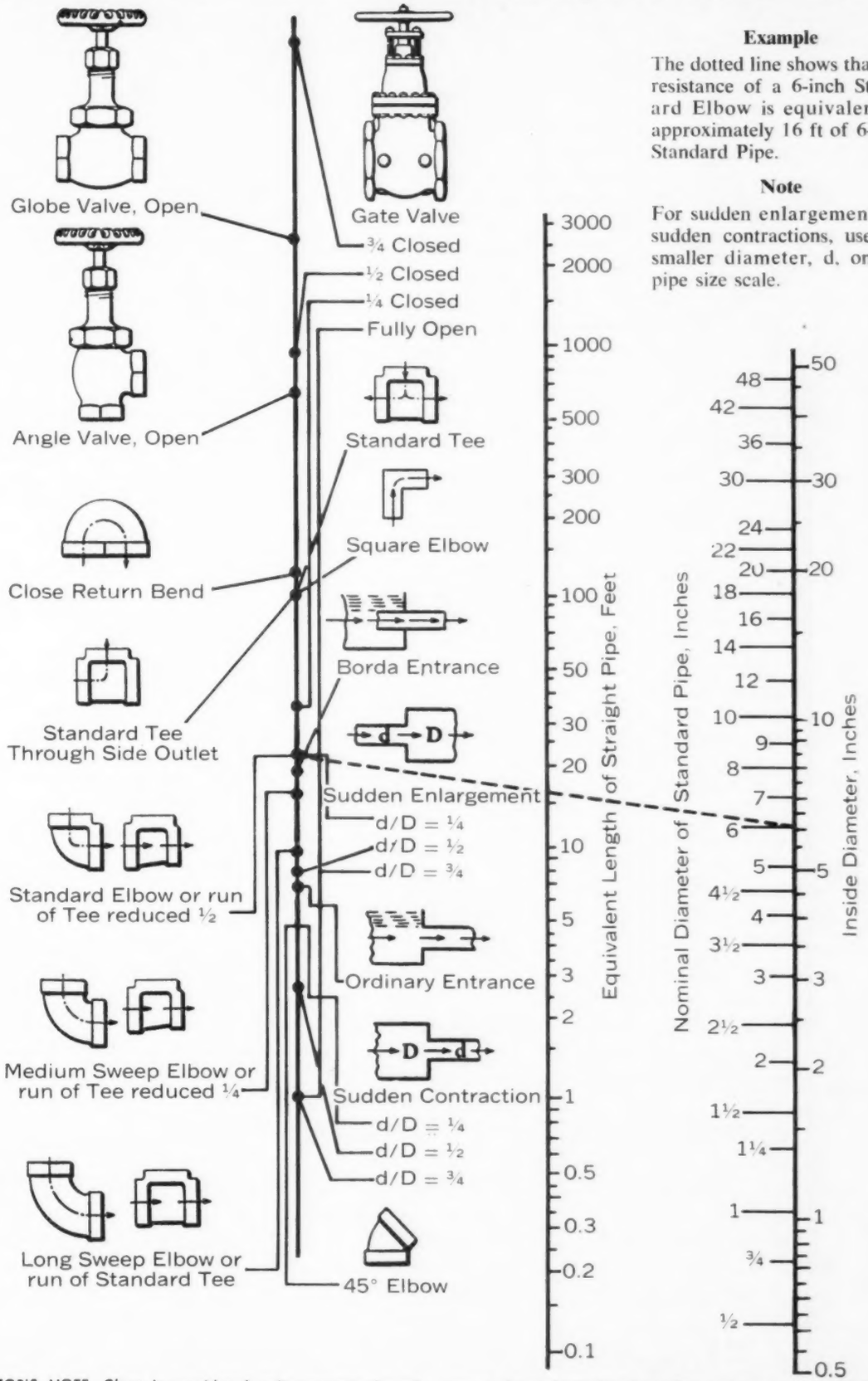
Size	C	Q	Size	C	Q
1 x1 x3/4	1-1/2	1-1/2	4x 4x3-1/2	4-1/8	4
1 x1 x1/2	1-1/2	1-1/2	4x 4x3	4-1/8	3-7/8
			4x 4x2-1/2	4-1/8	3-3/4
1-1/4x1-1/4x1	1-7/8	1-7/8	4x 4x2	4-1/8	3-1/2
1-1/4x1-1/4x3/4	1-7/8	1-7/8	4x 4x1-1/2	4-1/8	3-3/8
1-1/4x1-1/4x1/2	1-7/8	1-7/8			
			5x 5x4	4-7/8	4-5/8
1-1/2x1-1/2x1-1/4	2-1/4	2-1/4	5x 5x3-1/2	4-7/8	4-1/2
1-1/2x1-1/2x1	2-1/4	2-1/4	5x 5x3	4-7/8	4-3/8
1-1/2x1-1/2x3/4	2-1/4	2-1/4	5x 5x2-1/2	4-7/8	4-1/4
1-1/2x1-1/2x1/2	2-1/4	2-1/4	5x 5x2	4-7/8	4-1/8
2 x2 x1-1/2	2-1/2	2-3/8	6x 6x5	5-5/8	5-3/8
2 x2 x1-1/4	2-1/2	2-1/4	6x 6x4	5-5/8	5-1/8
2 x2 x1	2-1/2	2	6x 6x3-1/2	5-5/8	5
2 x2 x3/4	2-1/2	1-3/4	6x 6x3	5-5/8	4-7/8
			6x 6x2-1/2	2-5/8	4-3/4
2-1/2x2-1/2x2	3	2-3/4			
2-1/2x2-1/2x1-1/2	3	2-5/8	8x 8x6	7	6-5/8
2-1/2x2-1/2x1-1/4	3	2-1/2	8x 8x5	7	6-3/8
2-1/2x2-1/2x1	3	2-1/4	8x 8x4	7	6-1/8
			8x 8x3-1/2	7	6
3 x3 x2-1/2	3-3/8	3-1/4			
3 x3 x2	3-3/8	3	10x10x8	8-1/2	8
3 x3 x1-1/2	3-3/8	2-7/8	10x10x6	8-1/2	7-5/8
3 x3 x1-1/4	3-3/8	2-3/4	10x10x5	8-1/2	7-1/2
			10x10x4	8-1/2	7-1/4
3-1/2x3-1/2x3	3-3/4	3-5/8			
3-1/2x3-1/2x2-1/2	3-3/4	3-1/2	12x12x10	10	9-1/2
3-1/2x3-1/2x2	3-3/4	3-1/4	12x12x8	10	9
3-1/2x3-1/2x1-1/2	3-3/4	3-1/8	12x12x6	10	8-5/8
			12x12x5	10	8-1/2

REDUCERS

Size	T	U	Size	T	U	Size	T	U	Size	T	U
1 x3/4			3 x2-1/2			6x5			14x12		
1 x1/2	2	2	3 x2			6x4			14x10	13	*
1 x3/8			3 x1-1/2	3-1/2	3-1/2	6x3-1/2	5-1/2	5-1/2	14x 8		
			3 x1-1/4			6x3					
1-1/4x1						6x2-1/2			16x14		
1-1/4x3/4	2	2	3-1/2x3						16x12	14	*
1-1/4x1/2			3-1/2x2-1/2			8x6			16x10		
			3-1/2x2	4	4	8x5			18x16		
1-1/2x1-1/4			3-1/2x1-1/2			8x4	6	6	18x14	15	*
1-1/2x1			3-1/2x1-1/4			8x3-1/2			18x12		
1-1/2x3/4	2-1/2	2-1/2									
1-1/2x1/2			4 x3-1/2			10x8			20x18		
			4 x3			10x6			20x16		
2 x1-1/2			4 x2-1/2	4	4	10x5	7	7	20x14	20	*
2 x1-1/4			4 x2			10x4			20x12		
2 x1	3	3	4 x1-1/2								
2 x1						12x10			24x20		
2 x3/4			5 x4			12x8	8	8	24x18	20	*
			5 x3-1/2			12x6			24x16		
2-1/2x2			5 x3	5	5	12x5					
2-1/2x1-1/2	3-1/2	3-1/2	5 x2-1/2						*On application		
2-1/2x1-1/4			5 x2								
2-1/2x1											

Radius of bend for short Radius Elbows is equal to pipe diameter.

Resistance of Valves and Fittings to Fluid Flow



Example

The dotted line shows that the resistance of a 6-inch Standard Elbow is equivalent to approximately 16 ft of 6-inch Standard Pipe.

Note

For sudden enlargements or sudden contractions, use the smaller diameter, d, on the pipe size scale.

EDITOR'S NOTE: Chart is considered quite accurate for all sizes given for gas in pressure ranges where the Weymouth Formula or Panhandle Formula is used. In low pressure use, where the Spitzglass Formula is used, chart is reasonably accurate for mains 4-in. and larger. For smaller sizes, such as service lines 2-in. and smaller, pressure drops calculated by using chart may be in excess of actual practice, depending on pressure involved. In such cases, service might be designed oversize. Other values are presented in the section of this Handbook on "Gas Service Design" and "Installation of Gas Piping on Industrial and Commercial Premises (Table 1)."

Chart courtesy Crane Company.

WEIGHTS OF MECHANICAL JOINT PIPE FOR GAS

Standard thicknesses and weights of cast iron mechanical joint pipe centrifugally cast in metal and sand lined molds for gas

Note: Thicknesses in accordance with A.S.A. Specifications, 18,000 psi full length bursting tensile, 40,000 psi ring modulus of rupture. For pipe laid without blocks on flat bottom trench with tamped backfill under 5 feet of cover. For other conditions consult the manufacturer.

Size ins.	Thickness ins.	Outside Diam. ins.	Weight Based On 12 ft. Lgth.* Avg. per ft.	12 ft. Lgth.* per Lgth.	16 ft. Lgth.* Avg. per ft.	16 ft. Lgth.* per Lgth.	16½ ft. Lgth.* Avg. per ft.	16½ ft. Lgth.* per Lgth.	18 ft. Lgth.* Avg. per ft.	18 ft. Lgth.* per Lgth.	20 ft. Lgth.* Avg. per ft.	20 ft. Lgth.* per Lgth.
Class 10—10 Lb. Pressure												
4	.35(1)	4.80	16.6	200	16.4	260	16.3	270	16.2	290		
	or .38(2)	4.80	17.8	215	17.6	280	17.5	290	17.4	315		
6	.38(1)	6.90	26.1	315	25.7	410	25.6	420	25.5	460		
	or .41(2)	6.90	27.9	335	27.6	440	27.5	455	27.3	490		
8	.41	9.05	37.7	445	36.7	585	36.6	605	36.4	655		
10	.44	11.10	49.3	590	48.5	775	48.4	800	48.2	870		
12	.48	13.20	64.0	770	62.9	1005	62.8	1035	62.6	1125	62.3	1245
16	.50	17.40	90.7	1090	88.7	1420	88.6	1460	88.1	1585	87.6	1750
20	.57	21.60	128.7	1545	125.9	2015	125.7	2075	124.9	2250	124.2	2485
24	.63	25.80	170.2	2040	166.5	2665	166.1	2740	165.2	2975	164.2	3285
30	.73	32.00			241.5	3865	241.0	3975			238.0	4760
36	.81	38.30			322.4	5160						
42	.90	44.50			416.5	6665						
48	.98	50.80			519.0	8305						
Class 50—50 Lb. Pressure												
4	.35(1)	4.80	16.6	200	16.4	260	16.3	270	16.2	290		
	or .38(2)	4.80	17.8	215	17.6	280	17.5	290	17.4	315		
6	.38(1)	6.90	26.1	315	25.7	410	25.6	420	25.5	460		
	or .41(2)	6.90	27.9	335	27.6	440	27.5	455	27.3	490		
8	.41	9.05	37.2	445	36.7	585	36.6	605	36.4	655		
10	.44	11.10	49.3	590	48.5	775	48.4	800	48.2	870		
12	.48	13.20	64.0	770	62.9	1005	62.8	1035	62.6	1125	62.3	1245
16	.50	17.40	90.7	1090	88.7	1420	88.6	1460	88.1	1585	87.6	1750
20	.57	21.60	128.7	1545	125.9	2015	125.7	2075	124.9	2250	124.2	2485
24	.63	25.80	170.2	2040	166.5	2665	166.1	2740	165.2	2975	164.2	3285
30	.79	32.00			259.5	4150	259.0	4275			256.0	5120
36	.87	38.30			343.9	5500						
42	.97	44.50			445.7	7130						
48	1.06	50.80			557.1	8915						
Class 100—100 Lb. Pressure												
4	.35(1)	4.80	16.6	200	16.4	260	16.3	270	16.2	290		
	or .38(2)	4.80	17.8	215	17.6	280	17.5	290	17.4	315		
6	.38(1)	6.90	26.1	315	25.7	410	25.6	420	25.5	460		
	or .41(2)	6.90	27.9	335	27.6	440	27.5	455	27.3	490		
8	.41	9.05	37.2	445	36.7	585	36.6	605	36.4	655		
10	.44	11.10	49.3	590	48.5	775	48.4	800	48.2	870		
12	.48	13.20	64.0	770	62.9	1005	62.8	1035	62.6	1125	62.3	1245
16	.54	17.40	97.1	1165	95.0	1520	94.9	1565	94.5	1700	94.0	1880
20	.62	21.60	138.7	1665	135.9	2175	135.7	2240	134.9	2430	134.2	2685
24	.68	25.80	182.2	2185	178.5	2855	178.1	2940	177.2	3190	176.2	3525
Class 150—150 Lb. Pressure												
4	.35(1)	4.80	16.6	200	16.4	260	16.3	270	16.2	290		
	or .38(2)	4.80	17.8	215	17.6	280	17.5	290	17.4	315		
6	.38(1)	6.90	26.1	315	25.7	410	25.6	420	25.5	460		
	or .41(2)	6.90	27.9	335	27.6	440	27.5	455	27.3	490		
8	.41	9.05	37.2	445	36.7	585	36.6	605	36.4	655		
10	.44	11.10	49.3	590	48.5	775	48.4	800	48.2	870		
12	.48	13.20	64.0	770	62.9	1005	62.8	1035	62.6	1125	62.3	1245

* Including Bell. Calculated weight of pipe rounded off to nearest 5 pounds.
(1) Class 22 thickness.
(2) Class 23 thickness offers increased factor of safety and is recommended for use in areas of dense population and heavy traffic.
References: A.S.A.—A-21.7—pipe cast in metal molds. A.S.A.—A-21.9—pipe cast in sand lined molds. A.S.A.—A-21.11—mechanical joints.

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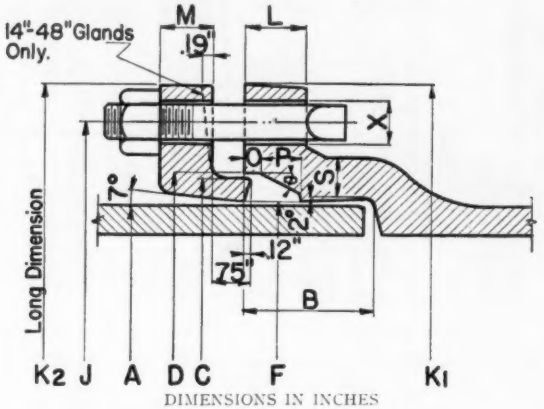
3 to 48-IN. STD. MECHANICAL JOINT DIMENSIONS



DIMENSIONS IN INCHES

NOTES:

1. The thickness of the bell, S, shall in all cases be equal to and generally exceeds by at least 10% the nominal wall thickness of the pipe or fitting of which it is a part.
2. Cored holes may be tapered an additional 0.06" in diameter.
3. In case of ovalness of the spigot O.D., the mean diameter measured by a circumferential tape shall not be less than the minimum diameter shown in the table. The minor axis shall not be less than the above minimum diameter plus an additional minus tolerance of .04" for sizes 8" through 12", and .07" for sizes 14" through 24".
4. K_2 is O.D. of glands across bolt holes, outside of gland may be polygon shape.
5. Dimensions of 30"—48" sizes are tentative.

DIMENSIONS IN INCHES

SIZE	A	B	C	D	F	φ	X	J	K_1 Cent. Pipe	K_1 Fit Cast Pipe and Fittings	K_2	L	M	O	P	S Cent. Pipe	S Pit Cast Pipe and Fittings	BOLTS No.	BOLTS Size	BOLTS Lgth.
3	±.06 3.96	2.50	±.04 4.84	+.06 −.04 4.94	+.07 −.03 4.06	28°	+.06 −.0 3/4	±.06 6.19	−.06 7.62	−.12 7.69	−.12 7.69	−.06 .94	−.06 .62	.31	.63	−.05 .47	−.10 .52	4	5/8	3
4	±.06 4.80	2.50	±.04 5.92	+.06 −.04 6.02	+.07 −.03 4.50	28°	+.06 −.0 7/8	±.06 7.50	−.06 9.06	−.12 9.12	−.12 9.12	−.06 1.00	−.06 .75	.31	.75	−.05 .55	−.10 .65	4	3/4	3 1/2
6	±.06 6.90	2.50	±.04 8.02	+.06 −.04 8.12	+.07 −.03 7.00	28°	+.06 −.0 7/8	±.06 9.50	−.06 11.06	−.12 11.12	−.12 11.12	−.06 1.06	−.06 .88	.31	.75	−.05 .60	−.10 .70	6	3/4	3 1/2
8	±.06 9.05	2.50	±.04 10.17	+.06 −.04 10.27	+.07 −.03 9.15	28°	+.06 −.0 7/8	±.06 11.75	−.06 13.31	−.12 13.37	−.12 13.37	−.08 1.12	−.08 1.00	.31	.75	−.05 .66	−.12 .75	6	3/4	4
10	±.06 11.10	2.50	+.06 −.04 12.22	+.06 −.04 12.34	+.07 −.03 11.20	28°	+.06 −.0 7/8	±.06 14.00	−.06 15.62	−.12 15.69	−.12 15.62	−.08 1.19	−.08 1.00	.31	.75	−.06 .72	−.12 .80	8	3/4	4
12	±.06 13.20	2.50	+.06 −.04 14.32	+.06 −.04 14.44	+.07 −.03 13.30	28°	+.06 −.0 7/8	±.06 16.25	−.06 17.88	−.12 17.94	−.12 17.88	−.08 1.25	−.08 1.00	.31	.75	−.06 .79	−.12 .85	8	3/4	4
14	+.05 −.08 15.30	3.50	+.07 −.05 16.40	+.07 −.05 16.54	+.06 −.07 15.44	28°	+.06 −.0 7/8	±.06 18.75	−.08 20.25	−.12 20.31	−.12 20.25	−.12 1.31	−.12 1.25	.31	.75	−.08 .85	−.12 .89	10	3/4	4
16	+.05 −.08 17.40	3.50	+.07 −.05 18.50	+.07 −.05 18.64	+.06 −.07 17.54	28°	+.06 −.0 7/8	±.06 21.00	−.08 22.50	−.12 22.56	−.12 22.50	−.12 1.38	−.12 1.31	.31	.75	−.08 .91	−.12 .97	12	3/4	4 1/2
18	+.05 −.08 19.50	3.50	+.07 −.05 20.60	+.07 −.05 20.74	+.06 −.07 19.64	28°	+.06 −.0 7/8	±.06 23.25	−.08 24.75	−.15 24.83	−.15 24.75	−.12 1.44	−.12 1.38	.31	.75	−.08 .97	−.15 1.05	12	3/4	4 1/2
20	+.05 −.08 21.60	3.50	+.07 −.05 22.70	+.07 −.05 22.84	+.06 −.07 21.74	28°	+.06 −.0 7/8	±.06 25.50	−.08 27.00	−.15 27.08	−.15 27.00	−.12 1.50	−.12 1.44	.31	.75	−.08 1.03	−.15 1.12	14	3/4	4 1/2
24	+.05 −.08 25.80	3.50	+.07 −.05 26.90	+.07 −.05 27.04	+.06 −.07 25.94	28°	+.06 −.0 7/8	±.06 30.00	−.08 31.50	−.15 31.58	−.15 31.50	−.12 1.62	−.12 1.56	.31	.75	−.08 1.08	−.15 1.22	16	3/4	5
30	32.00	4.00	33.29	33.46	32.17	20°	1 1/8	36.88	39.12	39.12	39.12	1.81	2.00	.38	1.00	1.20	1.50	20	1	5 1/2
36	38.30	4.00	39.59	39.76	38.47	20°	1 1/8	43.75	46.00	46.00	46.00	2.00	2.00	.38	1.00	1.35	1.80	24	1	5 1/2
42	44.50	4.00	45.79	45.96	44.67	20°	1 1/8	50.62	53.12	53.12	53.12	2.00	2.00	.38	1.00	1.48	1.95	28	1 1/4	6
48	50.80	4.00	52.09	52.26	50.97	20°	1 1/8	57.50	60.00	60.00	60.00	2.00	2.00	.38	1.00	1.61	2.20	32	1 1/4	6

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STANDARD THICKNESSES OF CAST IRON PIT CAST PIPE FOR GAS

THICKNESS IN INCHES. WORKING PRESSURE IN POUNDS PER SQUARE INCH.
THICKNESSES INCLUDE ALLOWANCES FOR FOUNDRY PRACTICE AND CORROSION
Laying Condition A — Flat Bottom Trench, Without Blocks, Untamped Backfill
Laying Condition B — Flat Bottom Trench, Without Blocks, Tamped Backfill
Laying Condition C — Pipe Laid on Blocks, Untamped Backfill
Laying Condition D — Pipe Laid on Blocks, Tamped Backfill

Size Inches	Working Pressure	3½ FEET OF COVER				5 FEET OF COVER				8 FEET OF COVER			
		Laying Condition				Laying Condition				Laying Condition			
		A	B	C	D	A	B	C	D	A	B	C	D
4	10	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.46	.40
	50	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40	.50	.40
	100	.40	.40	.40	.40	.40	.40	.43	.40	.40	.40	.50	.40
	150	.40	.40	.40	.40	.40	.40	.43	.40	.40	.40	.50	.40
6	10	.43	.43	.46	.43	.43	.43	.50	.43	.43	.43	.54	.43
	50	.43	.43	.46	.43	.43	.43	.50	.43	.43	.43	.54	.43
	100	.43	.43	.46	.43	.43	.43	.50	.43	.43	.43	.58	.43
	150	.43	.43	.50	.43	.43	.43	.50	.43	.43	.43	.58	.43
8	10	.46	.46	.50	.46	.46	.46	.54	.46	.46	.46	.58	.46
	50	.46	.46	.54	.46	.46	.46	.54	.46	.46	.46	.63	.46
	100	.46	.46	.54	.46	.46	.46	.58	.46	.46	.46	.63	.46
	150	.46	.46	.54	.46	.46	.46	.58	.46	.46	.46	.63	.46
10	10	.50	.50	.54	.50	.50	.50	.58	.50	.50	.50	.68	.50
	50	.50	.50	.58	.50	.50	.50	.58	.50	.50	.50	.68	.54
	100	.50	.50	.58	.50	.50	.50	.63	.50	.54	.50	.68	.54
	150	.50	.50	.58	.50	.50	.50	.63	.50	.54	.50	.68	.58
12	10	.54	.54	.58	.54	.54	.54	.63	.54	.54	.54	.68	.58
	50	.54	.54	.58	.54	.54	.54	.63	.54	.58	.54	.73	.58
	100	.54	.54	.63	.54	.54	.54	.63	.54	.58	.58	.73	.58
	150	.54	.54	.63	.58	.58	.54	.68	.58	.63	.58	.79	.63
16	10	.58	.58	.68	.58	.58	.58	.68	.63	.68	.63	.79	.68
	50	.58	.58	.68	.63	.63	.58	.73	.63	.68	.63	.79	.73
	100	.63	.58	.73	.63	.63	.58	.73	.68	.73	.68	.85	.73
20	10	.66	.66	.77	.71	.71	.66	.83	.71	.77	.71	.90	.83
	50	.71	.66	.77	.71	.71	.66	.83	.77	.77	.71	.90	.83
	100	.71	.66	.83	.77	.77	.71	.83	.77	.83	.77	.97	.83
24	10	.74	.74	.80	.74	.80	.74	.86	.80	.86	.80	.93	.86
	50	.80	.74	.86	.80	.80	.74	.93	.86	.86	.80	1.00	.93
	100	.80	.74	.93	.86	.86	.80	.93	.86	.93	.86	1.00	.93
30	10	.87	.87	.94	.87	.94	.87	1.02	.94	1.02	.87	1.10	1.02
	50	.94	.87	1.02	.94	.94	.87	1.10	1.02	1.10	.94	1.19	1.10
36	10	1.05	.97	1.05	.97	1.05	.97	1.13	1.05	1.13	.97	1.22	1.13
	50	1.05	.97	1.13	1.05	1.13	.97	1.22	1.13	1.22	1.05	1.32	1.22
42	10	1.16	1.07	1.16	1.07	1.16	1.07	1.25	1.16	1.35	1.07	1.35	1.25
	50	1.16	1.07	1.25	1.16	1.25	1.07	1.35	1.25	1.35	1.16	1.46	1.35
48	10	1.27	1.18	1.37	1.18	1.37	1.18	1.37	1.27	1.48	1.18	1.60	1.37
	50	1.27	1.18	1.37	1.27	1.37	1.18	1.48	1.37	1.48	1.27	1.60	1.48

NOTE: This table is taken from ASA A21.3

STANDARD THICKNESS OF CAST IRON GAS PIPE CENTRIFUGALLY CAST IN METAL MOLDS OR SAND LINED MOLDS

THICKNESS IN INCHES. WORKING PRESSURE IN POUNDS PER SQUARE INCH.
THICKNESSES INCLUDE ALLOWANCES FOR FOUNDRY PRACTICE AND CORROSION
Laying Condition A — Flat Bottom Trench, Without Blocks, Untamped Backfill
Laying Condition B — Flat Bottom Trench, Without Blocks, Tamped Backfill
Laying Condition C — Pipe Laid on Blocks, Untamped Backfill
Laying Condition D — Pipe Laid on Blocks, Tamped Backfill

Size Inches	Working Pressure	3½ FEET OF COVER				5 FEET OF COVER				8 FEET OF COVER			
		Laying Condition				Laying Condition				Laying Condition			
		A	B	C	D	A	B	C	D	A	B	C	D
4	10	.35[1]	.35	.35	.35	.35	.35	.35	.35	.35	.35	.41	.35
		.38[2]	.38	.38	.38	.38	.38	.38	.38	.38	.38	.41	.38
	50	.35[1]	.35	.35	.35	.35	.35	.35	.35	.35	.35	.41	.35
		.38[2]	.38	.38	.38	.38	.38	.38	.38	.38	.38	.41	.38
	100	.35[1]	.35	.35	.35	.35	.35	.35	.35	.35	.35	.41	.35
		.38[2]	.38	.38	.38	.38	.38	.38	.38	.38	.38	.41	.38
	150	.35[1]	.35	.35	.35	.35	.35	.38	.35	.35	.35	.41	.35
		.38[2]	.38	.38	.38	.38	.38	.38	.38	.38	.38	.41	.38
6	10	.38[1]	.38	.41	.38	.38	.38	.41	.38	.38	.38	.48	.38
		.41[2]	.41	.41	.41	.41	.41	.41	.41	.41	.41	.48	.41
	50	.38[1]	.38	.41	.38	.38	.38	.41	.38	.38	.38	.48	.38
		.41[2]	.41	.41	.41	.41	.41	.41	.41	.41	.41	.48	.41
	100	.38[1]	.38	.41	.38	.38	.38	.44	.38	.38	.38	.48	.38
		.41[2]	.41	.41	.41	.41	.41	.44	.41	.41	.41	.48	.41
	150	.38[1]	.38	.41	.38	.38	.38	.44	.38	.38	.38	.48	.38
		.41[2]	.41	.41	.41	.41	.41	.44	.41	.41	.41	.48	.41
8	10	.41	.41	.44	.41	.41	.41	.48	.41	.41	.41	.52	.41
	50	.41	.41	.44	.41	.41	.41	.48	.41	.41	.41	.52	.41
	100	.41	.41	.48	.41	.41	.41	.48	.41	.41	.41	.56	.41
	150	.41	.41	.48	.41	.41	.41	.48	.41	.41	.41	.56	.41
10	10	.44	.44	.48	.44	.44	.44	.52	.44	.44	.44	.60	.44
	50	.44	.44	.48	.44	.44	.44	.52	.44	.44	.44	.60	.44
	100	.44	.44	.52	.44	.44	.44	.52	.44	.44	.44	.60	.48
	150	.44	.44	.52	.44	.44	.44	.56	.44	.48	.44	.60	.48
12	10	.48	.48	.52	.48	.48	.48	.56	.48	.48	.48	.60	.52
	50	.48	.48	.52	.48	.48	.48	.56	.48	.48	.48	.60	.52
	100	.48	.48	.56	.48	.48	.48	.56	.48	.52	.48	.65	.52
	150	.48	.48	.56	.48	.48	.48	.56	.48	.52	.48	.65	.52
16	10	.54	.50	.58	.54	.54	.50	.63	.58	.58	.54	.73	.63
	50	.54	.50	.63	.54	.54	.50	.63	.58	.63	.58	.73	.63
	100	.54	.54	.63	.58	.58	.54	.68	.58	.63	.58	.73	.68
20	10	.62	.57	.67	.62	.62	.57	.72	.67	.67	.62	.78	.72
	50	.62	.57	.72	.62	.67	.57	.72	.67	.72	.62	.78	.72
	100	.62	.57	.72	.67	.67	.62	.78	.67	.72	.67	.84	.78
24	10	.68	.63	.73	.68	.73	.63	.79	.73	.79	.68	.85	.79
	50	.68	.63	.79	.68	.73	.63	.79	.73	.79	.73	.85	.79
	100	.73	.63	.79	.73	.73	.68	.85	.79	.79	.73	.92	.85
30	10	.79	.73	.85	.79	.85	.73	.92	.85	.92	.79	.99	.92
	50	.85	.73	.85	.85	.85	.79	.92	.85	.92	.85	.99	.92
36	10	.87	.81	.94	.87	.94	.81	1.02	.94	1.02	.87	1.10	1.02
	50	.94	.81	1.02	.94	1.02	.87	1.10	.94	1.10	.94	1.19	1.02
42	10	1.05	.90	1.05	.97	1.05	.90	1.13	1.05	1.13	.97	1.22	1.13
	50	1.05	.90	1.13	1.05	1.13	.97	1.13	1.05	1.22	1.05	1.32	1.13
48	10	1.14	.98	1.14	1.06	1.14	.98	1.23	1.14	1.33	1.06	1.33	1.23
	50	1.14	.98	1.23	1.14	1.23	1.06	1.33	1.14	1.33	1.14	1.44	1.33

[1]Class 22 Thickness.
[2]Class 23 Thickness offers increased factor of safety and is recommended for use in areas of dense population and heavy traffic.

NOTE: This table is taken from ASA A21.7 and A21.9

PLASTIC PIPE DATA

Increasing use by the gas distribution industry of pipe and fittings made from plastic materials has been responsible for adding this section on "Plastic Pipe" to the *Gas Handbook Issue*. The relative newness of pipe made from plastic materials has been accompanied by a lack of technical standards. Experimentation and application however, are increasing the knowledge necessary for development of such standards. Data in this section is based on recommendations of the AGA Subcommittee on Plastic Pipe Standards, and standards of The Society of the Plastics Industry. *Data in the accompanying tables should be considered as recommendations and not standards.*

In discussing plastic materials, it should be understood that the word *plastic* is a generic term, applying to a distinct group of materials, just as the word *metal* applies to a distinct group of materials. Each of the numerous plastic materials has its own peculiar physical and chemical properties that must be considered before applicability and serviceability for any end use can be determined.

Practically all commercial plastic pipe available will give good performance when applied within its pressure and temperature limitations. The AGA subcommittee has recommended four types of plastic materials for use in the distribution of natural gas. None of the four are recommended for gas containing aromatic hydrocarbons, which generally excludes their use for distribution of manufactured gas.

Recommended plastic materials are:

a. Normal impact polyvinyl chloride—Type I.

b. High impact polyvinyl chloride—Type II.

c. Styrene copolymer rubber resin blend (a butadiene-styrene-acrylonitrile copolymer)—B or BE grade.

d. Cellulose acetate butyrate—formulas, medium hard flow, #435, #205, and #460 in clear or black, and #265 in black.

For calculation of the burst values of plastic materials, two universally recognized formulas, Barlow's or Lamé's, have been proved to be acceptable. Use of the formula that provides the lowest value for the bursting strength is specifically recommended.

Barlow's formula is:

$$\text{Burst} = \frac{2 \times T \times S}{OD}$$

Lamé's formula is:

$$\text{Burst} = \frac{S \times (OD^2 - ID^2)}{(OD^2 + ID^2)}$$

In each formula,

T = wall thickness,

S = allowable tensile strength (psi),

OD = outside diameter,

ID = inside diameter.

Working stress values for the specific plastic materials, to be used in either Barlow's or Lamé's formula to calculate burst values of these materials at operating temperatures not in excess of 100 F are:

a. Normal impact polyvinyl chloride—Type I . . . . . 1200 psi

b. High impact polyvinyl chloride—Type II . . . . . 1000 psi

c. Styrene copolymer rubber resin blends . . . . . 1000 psi

d. Cellulose acetate butyrate—all recommended formulas . . . 700 psi

Minimum wall thickness recommendations for the various kinds and sizes of thermoplastic pipe to be used as underground natural gas distribution piping, and subjected to pressures and temperatures not in excess of 60 psi and 100 F, are given in Table 1.

These recommended pipe wall thicknesses are based on hoop stress values less an appreciable safety factor. They are minimum, not only to withstand the pressures and temperatures noted, but to withstand normal earth and traffic loads, and normal transport, handling, and installation stresses. Caution should be observed, of course, in the use of mechanical and hand earth compaction equipment during trench backfill operations.

Tables 2 and 3 give pertinent technical data on recommended SWP (solvent weld pipe) and IPS (iron pipe sizes) dimensions for plastic pipe in various sizes. Again, it should be pointed out that these tables reflect recommendations, and, as will be noted, there is variance in dimensions, tolerances, pressures, etc., among the various types of pipe due to inherent differences in materials. The reader considering plastic pipe is urged to consult the catalogs and specification sheets of the various pipe manufacturers on their specific products.

For gas distribution work the AGA subcommittee recommends that plastic pipe in all sizes listed in Table 1 be connected by the solvent and/or cement weld process. None of the pipe sizes in Table 1 should be threaded because of insufficient wall thickness after threading and the possibility of thread deformation.

Solvent welding techniques are applicable to both thin-wall and standard size plastic pipe for plastic-to-plastic assembly. For plastic-to-metal assembly, various types of inserts and couplings are available. Suggested joining methods vary with manufacturers; instructions from the manufacturer should be consulted and followed.

TABLE 1.

Recommendations of AGA Subcommittee on Plastic Pipe Standards

For Relining Existing Metal Lines

(Copper Tube Sizes)

Nominal Size	Outside Diameter	Minimum Wall Thickness: Styrene Copolymer Rubber Resin Blend and High Impact PVC—Type II	Minimum Wall Thickness: Normal Impact PVC—Type I	Minimum Wall Thickness: Cellulose Acetate Butyrate (All formulas Recommended)
½	0.625	0.062	0.062	0.062
¾	0.875	0.062	0.062	0.062
1	1.125	0.062	0.062	0.062
1¼	1.375	0.062	0.062	0.062
1¾	1.875	0.062	0.062	0.080

For New Services and Mains

(Iron Pipe Sizes)

Nominal Size	Outside Diameter	Minimum Wall Thickness: Styrene Copolymer Rubber Resin Blend and High Impact PVC—Type II	Minimum Wall Thickness: Normal Impact PVC—Type I	Minimum Wall Thickness: Cellulose Acetate Butyrate (All formulas Recommended)
½	0.840	0.090	0.090	0.090
¾	1.050	0.090	0.090	0.090
1	1.315	0.090	0.090	0.090
1¼	1.660	0.090	0.090	0.090
1½	1.900	0.090	0.090	0.090
2	2.375	0.090	0.090	0.110
2½	2.875	0.110	0.100	0.135
3	3.500	0.125	0.120	0.160
4	4.500	0.155	0.145	0.205
5	5.563	0.190	0.170	0.250
6	6.625	0.220	0.200	0.300

NOTE: A flow chart for plastic pipe, based on Schedule 40 size pipe, will be found on page 78 of this Handbook Issue.

$$\text{Burst} = \frac{2 \times T \times S}{OD}$$

6	6.625	0.220	0.200	0.300

78 of this Handbook Issue.

TABLE 2.

Technical Data for SWP Plastic Pipe.

Recommended Standard Dimensions					Styrene Copolymer Rubber Resin Blend*		Cellulose Acetate Butyrate Schedule A**			Cellulose Acetate Butyrate Schedule B***		
Nominal Size (In.)	Outside Diameter (In.)	Inside Diameter (In.)	Wall Thickness (In.)	Tolerance (OD-In.) ±	Max. Working Pressure (Psig @ 73.4F)	Nominal Weight lb/100 ft	Wall Thickness (In.)	Tolerance (OD-In.) ±	Nominal Weight lb/100 ft	Wall Thickness (In.)	Tolerance (OD-In.) ±	Nominal Weight lb/100 ft
½	0.600	0.500	0.050	0.005	200	4.0	0.050	0.003	4.50	0.050	0.003	4.5
¾	0.855	0.750	0.053	0.005	150	5.8	0.053	0.003	6.95	0.060	0.004	7.8
1	1.140	1.000	0.070	0.005	150	10.8	0.060	0.004	10.60	0.080	0.004	13.9
1¼	1.420	1.250	0.085	0.005	150	17.5	0.075	0.004	16.44	0.100	0.006	21.5
1½	1.730	1.500	0.115	0.006	150	26.0	0.092	0.005	24.50	0.125	0.007	32.8
2	2.250	2.000	0.125	0.008	140	43.1	0.120	0.006	41.75	0.160	0.009	54.8
2½	2.570	2.320	0.125	0.008	125	—	0.135	0.007	53.66	0.185	0.011	72.0
3	3.250	3.000	0.125	0.010	100	61.0	0.175	0.010	87.7	0.235	0.015	115.5
3½	3.660	3.360	0.150	0.011	100	—	0.195	0.012	110.4	0.260	0.017	144.3
4	4.100	3.800	0.150	0.012	90	96.5	0.220	0.014	139.5	0.295	0.020	183.2
5	5.110	4.750	0.180	0.014	90	—	0.275	0.018	217.0	0.365	0.025	282.7
6	6.220	5.750	0.230	0.016	90	170.0	0.335	0.022	321.9	0.445	0.030	419.4

*Based on use of recommended standard pipe dimensions. **Maximum working pressure = 75 psi @ 73.4 F. ***Maximum working pressure = 100 psi @ 73.4 F.

TABLE 3.

Technical Data on IPS Plastic Pipe.

		SCHEDULE 40						SCHEDULE 80					
			PVC Types I and II			Styrene Copolymer Rubber Resin			PVC Types I and II				Styrene Copolymer Rubber Resin
Nominal Size (In.)	Outside Diameter (In.)	Wall Thickness (In.)	Weight lb/ft I & II	Recommended Working Pressure (psig @ 75F) Type I	Type II	Weight lb/ft	Recommended Working Pressure (psig @ 75F)	Wall Thickness (In.)	Weight lb/ft Type I	Type II	Recommended Working Pressure (psig @ 75F) Type I	Type II	Weight lb/ft	Recommended Working Pressure (psig @ 75F)
½	0.840	0.109	0.157	120	100	0.12	75	0.147	0.201	0.185	250	215	0.15	150
¾	1.050	0.113	0.209	120	100	0.16	75	0.154	0.270	0.251	215	175	0.20	150
1	1.315	0.133	0.310	120	100	0.23	60	0.179	0.401	0.371	190	150	0.30	125
1¼	1.660	0.140	0.420	95	75	0.31	50	0.191	0.544	0.518	165	120	0.41	100
1½	1.900	0.145	0.503	95	75	0.37	45	0.200	0.671	0.618	160	110	0.50	90
2	2.375	0.154	0.675	75	60	0.50	40	0.218	0.928	0.858	140	90	0.70	75
2½	2.875	0.203	1.071	75	60	0.79	35	0.276	1.417	1.336	135	90	1.05	75
3	3.500	0.216	1.401	75	60	1.04	30	0.300	1.896	1.750	130	80	1.40	60
3½	4 000	0.226	1.684	60	50	—	—	0.318	2.312	2.180	130	75	—	—
4	4.500	0.237	1.995	60	50	1.50	30	0.337	2.770	2.560	125	70	2.00	60
6	6.625	0.280	3.640	60	50	2.62	25	0.432	6.730	5.780	120	60	3.85	50

Flow of Natural Gas in Plastic Pipe

Showing Pressure Drop in psi per 1000 ft of Pipe

Flow in cu ft per hour	Average Line Pressure in psi							Flow in cu ft per hour	Average Line Pressure in psi						
	5	10	20	30	40	50	60		5	10	20	30	40	50	60
	½-in. Pipe								¾-in. Pipe						
100	0.5	0.4	0.27	0.21	0.18	0.15	0.13	200	0.5	0.37	0.26	0.21	0.17	0.14	0.11
150	1.05	0.8	0.58	0.44	0.36	0.31	0.26	250	0.75	0.57	0.39	0.31	0.26	0.21	0.17
200	1.8	1.4	0.95	0.75	0.63	0.52	0.44	300	1.1	0.81	0.56	0.44	0.36	0.29	0.14
250	2.7	2.1	1.4	1.1	0.94	0.77	0.65	400	1.8	1.4	0.96	0.76	0.62	0.51	0.42
300	3.7	2.8	2.0	1.6	1.3	1.1	0.92	500	2.8	2.1	1.5	1.2	0.95	0.77	0.65
400	6.4	4.9	3.4	2.6	2.4	1.8	1.6	600	3.8	3.0	2.1	1.6	1.4	1.1	0.91
500	9.5	7.2	5.1	3.9	3.3	2.8	2.3	700	5.2	4.0	2.8	2.2	1.8	1.5	1.2
600	10.3	10.0	7.0	5.5	4.6	3.9	3.2	900	8.5	6.5	4.5	3.5	2.9	2.4	2.0
700	18	13	9.2	7.4	6.0	5.2	4.3	1,200	10.4	10.1	7.7	6.1	5.0	4.0	3.4
800	23	17	12	9.2	7.6	6.5	5.5	1,500	22	17	12	9.4	7.6	6.2	5.2
1,000	34	26	18	14	12	10	8.3	2,000	34	29	20	16	13	11	9
1,200	48	36	25	20	16	14	12	3,000	71	61	44	35	28	23	19
1,500	70	55	38	29	24	21	17								
	1-in. Pipe								1¼-in. Pipe						
400	0.5	0.39	0.28	0.23	0.19	0.15	0.13	800	0.49	0.38	0.26	0.21	0.17	0.14	0.12
500	0.76	0.59	0.43	0.34	0.28	0.24	0.20	900	0.60	0.47	0.33	0.26	0.21	0.18	0.15
600	1.1	0.82	0.60	0.48	0.39	0.33	0.28	1,100	0.90	0.67	0.48	0.38	0.32	0.26	0.22
800	1.8	1.4	1.0	0.81	0.66	0.56	0.48	1,500	1.6	1.2	0.85	0.66	0.56	0.47	0.40
1,000	2.7	2.1	1.5	1.2	1.0	0.85	0.72	2,000	2.8	2.1	1.5	1.2	0.97	0.80	0.67
1,200	3.9	3.0	2.1	1.7	1.4	1.2	1.0	2,500	4.2	3.2	2.3	1.8	1.5	1.2	1.0
1,400	5.1	3.9	2.8	2.3	1.9	1.6	1.3	3,000	6.0	4.5	3.2	2.5	2.1	1.7	1.4
1,600	6.6	5.1	3.6	2.9	2.4	2.0	1.7	4,000	10	8.0	5.6	4.3	3.6	3.0	2.5
2,000	9.9	7.6	5.4	4.4	3.6	3.0	2.6	5,000	16	12	8.5	6.6	5.5	4.6	3.9
2,500	15	11	8.2	6.6	5.4	4.5	3.9	6,000	23	17	12	9.2	7.8	6.5	5.5
3,000	21	16	11	9.3	7.5	6.4	5.4	7,000	30	23	16	13	10	8.6	7.2
4,000	35	27	19	16	13	11	9.1	8,000	40	30	21	16	14	11	9.5
5,000	53	41	29	23	19	16	14	9,000	49	37	26	20	17	14	12
6,000	75	57	41	33	27	23	19	10,000	60	45	32	24	21	17	14
	1½-in. Pipe								2-in. Pipe						
1,500	0.66	0.52	0.35	0.28	0.23	0.19	0.16	2,500	0.54	0.41	0.29	0.23	0.18	0.15	0.13
2,000	1.1	0.87	0.60	0.48	0.39	0.33	0.28	3,000	0.76	0.58	0.41	0.32	0.26	0.22	0.18
2,500	1.7	1.3	0.90	0.72	0.59	0.49	0.41	3,500	0.96	0.74	0.52	0.41	0.33	0.27	0.23
3,000	2.4	1.8	1.3	1.0	0.81	0.68	0.58	4,000	1.3	1.0	0.71	0.56	0.45	0.38	0.32
4,000	4.0	3.0	2.1	1.7	1.4	1.2	1.0	5,000	2.0	1.5	1.1	0.84	0.70	0.58	0.49
5,000	6.0	4.6	3.2	2.6	2.1	1.7	1.5	6,000	2.8	2.2	1.5	1.2	0.97	0.81	0.69
6,000	8.4	6.4	4.4	3.6	2.9	2.4	2.0	8,000	4.9	3.8	2.6	2.1	1.7	1.4	1.2
7,000	11	8.5	5.9	4.8	3.9	3.2	2.7	10,000	7.4	5.8	4.0	3.2	2.6	2.1	1.8
9,000	18	13	9.3	7.5	6.2	5.1	4.3	12,000	11	8.1	5.7	4.5	3.7	3.0	2.5
11,000	26	19	14	11	8.8	7.3	6.2	15,000	16	12	8.6	6.8	5.6	4.7	3.9
13,000	34	26	18	15	12	10	8.5	18,000	23	18	12	9.6	7.8	6.5	5.5
15,000	45	34	24	19	15	13	11	21,000	31	24	16	13	11	8.7	7.4
20,000	75	59	41	33	26	22	19	25,000	42	33	23	18	15	12	10
								30,000	59	46	32	25	21	17	14

Flow Table Instructions

The values of pressure drop in this table are based on Schedule 40 pipe size.

Because of the comparatively slight upstream-downstream pressure differences, the line pressures shown are the average values for any given system. For purposes of design, the average pressure indicated should be regarded as the downstream pressure, and the pressure drop should be added to this value to arrive at the upstream pressure.

EXAMPLE ON USE OF TABLES:

Service conditions:

900 cu ft per hour at 50 psi downstream pressure through a 1000 ft of ¾-in. pipe.

Find: The friction loss and upstream pressure necessary to meet the service requirements.

1. Select proper pipe table (¾-in.).
2. Line up the flow rate required (horizontally).
3. Line up the downstream pressure required (vertically).
4. Read off the friction loss (2.4 psi) at the intersection of the two lines.
5. Add 2.4 psi to the downstream pressure, 50 psi, to obtain the upstream pressure 52.4 psi.

Chart courtesy Kraloy Plastic Pipe Company, Inc.

Volume of Gas Lost in Blowdown of Line

(Gas volumes in table are in M cu. ft. per 1000 ft. of line)

Initial line pressure on shut-in section, lb. per sq. in., ga.	Nominal diameter of line, in.																	
	2	2½	3	3½	4	5	6	8	10	12	14	15	16	17	18	20	22	24
25	0.040	0.057	0.088	0.117	0.151	0.237	0.342	0.606	0.967	1.360	1.634	1.890	2.164	2.446	2.747	3.423	4.175	5.000
50	.080	.113	.175	.234	.302	.474	.685	1.213	1.934	2.722	3.269	3.781	4.330	4.894	5.495	6.849	8.353	10.00
75	.119	.170	.263	.352	.453	.711	1.027	1.819	2.901	4.082	4.903	5.670	6.494	7.340	8.242	10.27	12.53	15.00
100	0.159	0.227	0.350	0.469	0.603	0.948	1.369	2.425	3.868	5.443	6.538	7.561	8.659	9.788	10.99	13.70	16.71	20.01
125	.199	.284	.438	.586	.754	1.185	1.712	3.031	4.835	6.803	8.172	9.451	10.82	12.23	13.74	17.12	20.88	25.01
150	.239	.340	.526	.703	.905	1.422	2.054	3.638	5.803	8.165	9.808	11.34	12.99	14.68	16.49	20.55	25.06	30.01
175	.278	.397	.614	.821	1.056	1.660	2.397	4.246	6.772	9.529	11.45	13.24	15.16	17.14	19.24	23.98	29.25	35.03
200	0.318	0.454	0.701	0.937	1.207	1.896	2.738	4.850	7.735	10.88	13.07	15.12	17.32	19.57	21.98	27.39	33.41	40.01
225	.358	.511	.789	1.055	1.358	2.134	3.081	5.457	8.705	12.25	14.71	17.01	19.49	22.02	24.73	30.82	37.59	45.02
250	.397	.567	.876	1.172	1.508	2.370	3.422	6.061	9.668	13.60	16.34	18.90	21.64	24.46	27.47	34.23	41.75	50.00
275	.437	.624	.964	1.289	1.659	2.607	3.765	6.669	10.64	14.97	17.98	20.79	23.81	26.91	30.22	37.66	45.94	55.02
300	0.477	0.681	1.051	1.406	1.811	2.845	4.108	7.277	11.61	16.33	19.62	22.69	25.98	29.37	32.97	41.10	50.12	60.03
325	.517	.737	1.139	1.523	1.961	3.081	4.449	7.881	12.57	17.69	21.24	24.57	28.14	31.80	35.71	44.51	54.28	65.01
350	.557	.794	1.227	1.641	2.112	3.318	4.792	8.488	13.54	19.05	22.88	26.46	30.31	34.26	38.47	47.94	58.47	70.02
375	.596	.851	1.314	1.758	2.263	3.556	5.135	9.096	14.51	20.41	24.52	28.36	32.48	36.71	41.22	51.37	62.65	75.04
400	0.636	0.908	1.402	1.875	2.414	3.792	5.476	9.700	15.47	21.77	26.15	30.24	34.63	39.15	43.96	54.78	66.81	80.02
425	.676	.965	1.489	1.992	2.565	4.029	5.819	10.31	16.44	23.13	27.79	32.13	36.80	41.60	46.71	58.21	71.00	85.03
450	.716	1.021	1.577	2.110	2.716	4.267	6.162	10.91	17.41	24.50	29.42	34.03	38.97	44.05	49.46	61.64	75.18	90.04
475	.755	1.078	1.664	2.226	2.866	4.503	6.503	11.52	18.37	25.85	31.05	35.91	41.13	46.49	52.20	65.05	79.34	95.03
500	0.795	1.135	1.752	2.344	3.017	4.741	6.846	12.13	19.34	27.22	32.69	37.81	43.30	48.94	54.95	68.49	83.53	100.0
525	.835	1.192	1.840	2.461	3.169	4.978	7.190	12.73	20.31	28.58	34.33	39.70	45.47	51.39	57.71	71.92	87.71	105.1
550	.875	1.248	1.927	2.578	3.318	5.214	7.531	13.34	21.27	29.93	35.96	41.58	47.62	53.83	60.44	75.33	91.87	110.0
575	.915	1.305	2.015	2.695	3.470	5.452	7.874	13.95	22.24	31.30	37.59	43.48	49.79	56.28	63.20	78.76	96.06	115.0
600	0.954	1.362	2.103	2.813	3.621	5.689	8.217	14.55	23.21	32.66	39.23	45.37	51.96	58.73	65.95	82.19	100.2	120.1
625	.994	1.418	2.190	2.929	3.772	5.925	8.558	15.16	24.18	34.02	40.86	47.25	54.12	61.17	68.69	85.60	104.4	125.0
650	1.034	1.475	2.278	3.047	3.923	6.163	8.901	15.76	25.14	35.38	42.50	49.15	56.29	63.62	71.44	89.03	108.6	130.1
675	1.074	1.532	2.366	3.164	4.074	6.401	9.244	16.37	26.11	36.74	44.14	51.04	58.46	66.07	74.19	92.46	112.8	135.1
700	1.113	1.589	2.453	3.281	4.224	6.637	9.585	16.98	27.08	38.10	45.76	52.93	60.61	68.51	76.93	95.88	116.9	140.0
725	1.153	1.646	2.541	3.398	4.375	6.874	9.928	17.58	28.05	39.46	47.40	54.82	62.78	70.96	79.68	99.31	121.1	145.1
750	1.193	1.702	2.628	3.515	4.526	7.110	10.27	18.19	29.01	40.82	49.03	56.70	64.94	73.40	82.42	102.7	125.3	150.0
775	1.233	1.759	2.716	3.633	4.677	7.348	10.61	18.80	29.98	42.18	50.67	58.60	67.11	75.85	85.17	106.1	129.5	155.1
800	1.272	1.816	2.804	3.750	4.828	7.585	10.95	19.40	30.95	43.55	52.31	60.49	69.28	78.31	87.93	109.6	133.6	160.1
825	1.312	1.872	2.891	3.867	4.978	7.821	11.30	20.01	31.91	44.90	53.93	62.37	71.43	80.74	90.66	113.0	137.8	165.1
850	1.352	1.929	2.979	3.984	5.130	8.059	11.64	20.61	32.88	46.27	55.57	64.27	73.60	83.19	93.42	116.4	142.0	170.1
875	1.392	1.986	3.067	4.102	5.281	8.296	11.98	21.22	33.85	47.63	57.21	66.16	75.77	85.65	96.17	119.9	146.2	175.1

Note: Volumes are based on an atmospheric pressure of 14.65 lb. per sq. in., uncorrected for deviation from Boyle's law.

Example: A section of 18-in. line is partly blown-down between two main line gates at Stations 1563+49 and 2083+65, respectively. Initial pressure on the section is 750 lb. per sq. in. Pressure on the line at the end of the blow is 175 lb. per sq. in. What is the volume of gast lost during the blowdown?

Solution: 208365 — 156349 = 52016 ft., or 52.016 M ft. of line.

Volume of gas lost in blowdown of 1000 ft. of 18-in. line from 750 lb. per sq. in. ga. to atmospheric pressure = 82.42 M cu. ft.

Volume of gas lost in blowdown of 1000 ft. of 18-in. line from 175 lb. per sq. in. ga. to atmospheric pressure = 19.24 M cu. ft.

Volume of gas lost in blowdown of 1000 ft. of 18-in. line from 750 to 175 lb. per sq. in. ga. pressure = 63.18 M cu. ft.

63.18 times 52.016 = 3286.4 M cu. ft. of gas lost in blowdown

Testing of New Mains After Construction

All gas mains should be tested after construction, with the exception of tie-in sections that are used to divide a line into test sections or to connect piping necessary for such testing.

In designing a new main and determining test pressures, consideration should be given to the possibility of increasing the pressure of the main at some future time. The test pressure establishes the maximum allowable operating pressure and once the line is tested, the maximum allowable operating pressure on mains operating at hoop stresses of 30% or more of the specified minimum yield strength of the pipe cannot be raised until the line is retested.

Accordingly, the initial test should be made as high as possible in anticipation of future pressure increases in the line. In no case, though, should the maximum test pressure exceed a stress equal to the minimum specified yield strength of the pipe.

Testing Requirements

Mains designed to operate at a hoop stress of 30% or more of the specified minimum yield strength of the pipe should be given a field test after construction and before being placed in operation. This test determines the quality of workmanship and material, and the ability of the line to operate at its design pressure.

New mains installed in Class 1 locations (as defined in Par. 841 of ASA Code B 31.8-1958) are tested either with air or gas or hydrostatically to 1.1 times the maximum operating pressure. The test pressure should be maintained for a minimum continuous period of 24 hours.

New mains installed in Class 2 locations (as defined in Par. 841 of ASA Code B 31.8-1958) are tested with air or hydrostatically to 1.25 times the maximum operating pressure, with the test pressure maintained for a minimum continuous period of 24 hours.

New mains installed in Class 3 or 4 locations should be tested hydrostatically to 1.4 times the maximum operating pressure with a continuous minimum test period of 24 hours.

Whenever operational commitments or other valid reasons make it impractical to maintain the test pressure for 24 hours, the test pressure should be maintained as long as possible.

Hydrostatic tests should not be made when 1) ground temperature at pipe depth is 32 F or less, or might fall to that temperature before the hydrostatic test could be completed, or, 2) water of satisfactory quality is not available in sufficient quantity. In such cases, an air test to 1.1 times the maximum operating pressure can be made.

Leak Tests

Mains designed to operate at 100 psi or more must be tested after construction and before being placed in operation to demonstrate that they do not leak. If the test indicates a leak exists, the leak or leaks should be located and eliminated. Test procedure used should be capable of disclosing all leaks in the section being tested. In all cases where a line is to be stressed in a strength-proof test to 20% or more of the specified minimum yield strength of the pipe, using air or gas as the test medium, a leak test should be made at a pressure in the range from 100 psi to that required to produce a hoop stress of 20%.

Mains designed to operate at less than 100 psig must be tested before being placed in operation to determine that they are gas-tight. Gas may be used as a test medium at the maximum pressure available in the distribution system at the time of the test, provided it does not exceed 100 psig. In this case, the soap bubble test may be used to locate leaks if all joints are accessible during the test.

Testing at available distribution system pressures may not be adequate if protective coatings used on the pipe might seal a split pipe seam. If such coatings are used, a leak test pressure of 100 psig is recommended.

Safety During Tests

All testing of mains after construction should be done with due regard for the safety of employees and the public during the test.

When air or gas is used, suitable steps must be taken to keep persons not working on test operations out of the testing area during any period when pressures are raised above maximum operating pressure. Highway and railroad crossings should be manned and appropriate police, highway, and railroad officials should be notified when conditions warrant.

When water is used for testing, it is not necessary to keep persons not working on test operations out of the area, but they and appropriate police, highway, and railroad officials should be notified of the hydrostatic test when conditions warrant.

Testing Procedures — General

The line or section of main should be backfilled throughout its length before starting the test, except for necessary bellholes and open valve settings. Blind plates and caps should be installed or other suitable means used to prevent escape of the testing media from the line under test.

Gage pressures should be converted to absolute pressures by adding the barometric pressure existing at the deadweight gage at the times when pressure readings are made. Barometric pressures should be determined by using a reliable aneroid barometer, which has been checked by comparison with an accurate mercurial barometer.

Test gages. A minimum of two indicating gages are required, located at opposite ends of the section under test. If the pressure source is not located at either end gage location, a third indicating gage should be placed at the pressure source.

Twenty-four hour recording pressure and temperature gages should be installed to provide an official record of the test. Recording pressure gage should be accurate to within 5 psig in the test pressure range and recording temperature gage should be accurate to within 1 deg. F.

A deadweight gage or tester should be used to establish the official test pressure, and should be accurate to within 0.1 psig.

When water is used as a test medium, the elevation of the recording pressure gage, in relation to high and low points of the line, should be noted on the chart so that any elevation correction necessary can be made.

All gages and recording equipment should be located so that their accuracy will not be unduly affected by atmospheric conditions such as direct sunshine, etc. Tests should be conducted so that any change in line temperature between beginning and end of test is at a minimum.

All tie-in welds made after the test is completed, in order to facilitate pigging operations, water removal, etc., should be radiographically inspected if such inspection has been performed on the line.

Hydrostatic Testing

Hydrostatic or "water" testing is required in most populated areas when high test pressures are applied because the relative incompressibility of water reduces the hazard that might accompany a blowout. Using water, there would be no explosive decompression as with a gas at high pressure.

Simplest and sometimes least costly method of hydrostatic testing is the "vent and drain method." This requires installation of vents to bleed air from high points and drains to remove water at low points of the line. Water is injected into and removed from the line by gravity flow. Economy of this method depends upon the number of vents and drains needed and cost of obtaining an accurate profile needed to assure complete water removal.

More complex is the "pig" method in which water is injected into one end of a test section and air removed at the other end. A high pressure water pump is used

to obtain the test pressure. Air or gas is used to force the water out of the line after the test. In filling the line with water, a squeegee type pig is pushed through the line with water pressure, and the air is purged out ahead of the squeegee. Similarly, to assure complete removal of all water at end of the test, additional pigging is required, with air or gas used to move the pig or pigs.

Either method can be used, or a combination of the two methods, particularly the use of pigs plus vents when hilly terrain is involved.

Successful use of the pig method necessitates certain considerations:

1. *Line must be designed and constructed so that a squeegee type pig can be run the full length of the section to be tested.* This means that only long radius weld ells may be used, pipe must be of uniform nominal diameter, miters may not produce a deflection of more than 10 degrees, and valves and laterals usually must be cut into the line after the test.

2. *Special equipment is needed for insertion, propelling, and removal of pigs.* Test heads, water meters, check valves, pumps, filling and drain lines, gages and manifolds, etc., must be properly installed, operated, and removed.

3. *A means must be provided for controlling the speed of the pigs.* If a pig were allowed to run free and uncontrolled, it could develop enough momentum to cause structural damage to itself or the line.

Hydrostatic Testing Procedure

Preliminary engineering requirements. A profile survey should be made of the line to be tested prior to construction if inspection of the route on maps indicates elevation changes that would create excessive stresses during hydrostatic testing.

The inspection and/or survey should show:

1. Location of vents, drains, and drips.
2. Location of water fill pumps in relation to sources of water.
3. Differences in elevation that would create a static head of pressure.

Regardless of elevation changes, the minimum test pressure should be maintained at all points on the line for the duration of the test. Total pressure in the line will be equal to the indicated pressure at the gage locations plus or minus the effect of the static head pressure (elevation change in feet *times* 0.433) depending upon gage location.

Pressure at highest elevation equals indicated gage pressure plus static head pressure (static head from gage location to lowest elevation).

Pressure at lowest elevation equals indicated gage pressure minus the static head pressure (static head from gage location up to highest elevation).

Valves. If full-opening gate or plug-type valves are used in the line, the line can be isolated into test sections by using the valves. If restrictive plug-type valves are used in the line, the plug valve setting is customarily made after the line is tested and temporary testing facilities are used.

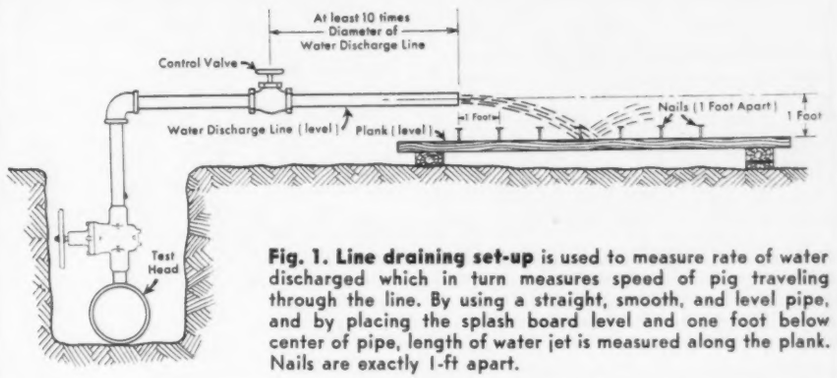


Fig. 1. Line draining set-up is used to measure rate of water discharged which in turn measures speed of pig traveling through the line. By using a straight, smooth, and level pipe, and by placing the splash board level and one foot below center of pipe, length of water jet is measured along the plank. Nails are exactly 1-ft apart.

The open pipe end should be elevated up out of ditch during the pigging operation.

Sources of water should be located well in advance of testing, as well as locations for disposal of water. Filters should be used whenever turbidity exceeds, normally, 150 parts per million. If the pH value of the water is less than 4, water should be chemically treated to maintain a pH value of not less than 4.

Whenever possible, the radius of bends in the line should not exceed 1½ pipe diameters to facilitate running squeegees and pigs.

Water fill and pressure pumps should be selected beforehand, preferably in conjunction with the contractor if the line is an outside contracted job, so that proper equipment will be available when testing operations are to begin.

Operating requirements. Water source should be checked periodically for turbidity and pH value during the filling operation.

The (continuing) mean ground temperature at pipe depth for the test operation should be checked periodically to insure that the temperature does not fall below 32 F. If ground temperatures are above 32 F but ambient temperature is at 32 F or below, exposed gage lines, test connections, etc., should be insulated to prevent freezing.

Before water fill operation is begun, a brush type cleaning pig should be run through the test section to remove construction debris, dirt, etc. The line should also be checked to insure that drains are closed and vents are open.

Some type of protection should be provided against water draining back in case of reduction of water system pressure or pump failure. A simple swing check valve can be used. When water is pumped from a tank or other open system — such as lake, canal, pond, etc.—care should be taken that air is not taken in through the swirling vortex. Suction lines should be screened to keep out vegetation, fish, etc.

Prior to entry of the water, a squeegee type pig should be inserted into the line. Water entering the line forces the pig ahead of it, and the pig forces the air out of the line.

The line should be filled with water at a steady rate so as to prevent formation of air pockets. Recording pressure and temperature stabilization.

When line is believed completely full of water, all vents and drains should be cracked open to insure that a full, steady stream of water comes out while the fill pump is operating. Vents should be kept open as long as bubbles come out.

As soon as line is completely full of water, all vents should be closed tightly. All connections to the line—vents, drains, valves, etc.—should be checked for leakage. If necessary, blind flanges and/or plates should be installed.

When line reaches desired test pressure and pressure has equalized, pressure pump should be stopped. As soon as test pressure and temperature are established and equalized throughout the line, the official test pressure is taken from the deadweight tester or gage and the official recording pressure and temperature charts are started.

The line should then be held under stabilized test pressure for a minimum 24-hour period.

Control of Pig Speed

Experience has indicated that the most successful rate of pig travel is between 2 and 3 miles per hour (176 to 264 ft per min). At this speed there is less "slippage" past the rubbers, there is less wasted time and less likelihood of damage or sticking. It is not always possible to attain a speed of 176 ft per min, but the pig should move as fast as is practical without exceeding the 264 ft per min maximum. If it should stop completely, the chance of mixing the fluids is greatly increased.

Since the pig is always either being pushed by water or is pushing water, it woud seem that its speed would be proportional to the rate at which water is fed into or drained out of the line. This is true, in general, but involves an additional consideration when filling the line.

Regulating the flow of water entering the line will control the filling pig speed if the terrain is level or rising in the direction of pig travel. When the pig reaches a certain point on a downhill slope, however, the weight of the water column between it and the top of the slope will cause it to continue running even if water injection is stopped completely. Addition of water at this stage will accelerate the

TABLE 1
Filling pig speed — ft per min

Water CFM	MAIN SIZE 4"	6"	8"	10"	12"	16"
10	108	47	27	17	12	8
20	216	94	55	34	24	15
30		140	82	52	37	23
40		187	110	69	49	31
50		234	137	86	61	38
60			164	104	73	46
70			192	121	82	53
80			219	138	98	61
90			243	155	110	67
100				173	122	76
110				190	135	84
120				204	147	92
130				225	159	99
140				242	171	107
150				260	183	115
160					195	122
170					208	130
180					220	137
190					232	145
200					244	153
210					256	160
220						168
230						176
240						183
250						191
260						198
270						206
280						214
290						221
300						229
320						244
340						260

$\frac{CFM}{A} = FPM$ Where: A = Flow area of main in sq ft
CFM is taken from water meter
FPM = Pig speed in ft per minute

motion. If this situation is allowed to develop, the result is that not only will the pig's position be "lost" but the tremendous force of the free running pig and hundreds of pounds of water could cause damage to the line. Furthermore, creation of a partial vacuum behind the pig increases the possibility of getting air into the line.

To prevent such occurrences it is necessary to provide pressure ahead of the pig (backpressure) at least equal to the pressure that might be caused by the weight of the water behind it. When this is done, the rate at which water is metered into the line does become proportional to the pig's speed. This backpressure requirement will vary with the terrain. It should be calculated by the engineering department for the entire length of each job. *(See page 20, January 1960 issue of American Gas Journal).*

Table 1 shows the relationship between actual pig speed and water injection rate in cfm that can be determined by timing the filling water meter. The table shows that, on smaller size lines, maximum allowable pig speed can be attained at relatively low rates of water flow. Water injection behind a 4-in. pig, for instance, should not exceed 25 cu ft per min. On the other hand, 25 cu ft per min in filling a 16-in. line would produce a pig speed of only 20 ft per min. At this rate, 4½ hours would be required to fill a mile of line. As the size of the line increases, it becomes increasingly important that larger volumes of water be available in order to keep filling time reasonable.

The problem of water removal after the test is much simpler, but no less important, than filling. Since in this case the pig is pushing water ahead, it is impossible for it to move faster than the water. All that is necessary to control pig speed is to control the water discharge; however, this requires water measurement.

Since an ordinary water meter would probably be damaged by construction debris or the high flow rate usually encountered in this operation, a simpler and sufficiently accurate device shown in Fig. 1 is used. It operates on the principle that the volume of water issuing from the end of a smooth, level, square-ended pipe is proportional to the horizontal length of the stream and the distance the water falls. The figures given in Table 2 under "Length of Water Jet" are based on a drop of one foot from the center of the pipe.

Thus, with a setup as shown, if the water line valve is controlled so that the water jet always hits a certain nail, the pig speed will remain constant regardless of how much excess pressure is applied at the other end. This speed, determined from Table 2, multiplied by the elapsed time, gives the distance of the pig from the sending head.

Backpressure

If the line is long and of large diameter, initial backpressure requirement may be high and additional air compressors would be required.

The following formula gives an approximation of the time in minutes required for one 105-cfm compressor to pump a line to required pressure when air hose lengths are kept to a minimum:
Where:

$$T = 0.0067 \times V \times P$$

T = time in minutes
V = volume of line in cu ft
P = initial backpressure required plus 15

Two 105-cfm compressors would do the job in one-half this time, three would do it in one-third the time, etc.

Filling Calculations

Table 1 gives pig speeds produced in various main sizes by various water flow rates. Table 3 shows water pressure drop per foot through various size lines at various flow rates. By using these tables, adequacy of any given size fill line can be roughly determined as follows:

1. Deduct maximum forecasted gage reading, plus 4 psi pig resistance, plus 16 psi backflow valve resistance (if used) from expected hydrant pressure.
2. Determine length of fill line required and add 25 ft equivalent length of fittings.
3. Divide the remaining pressure found above (1) by the total equivalent length of the fill line (2); this gives the allowable pressure loss in psi per ft.
4. Find this figure in Table 3 under the size fill line recommended and note the corresponding rate of flow.
5. From Table 1, opposite this rate of flow, and under the proper main size, read the expected minimum pig speed in feet per minute. If this speed is so slow as to require excessive time to fill the line, select a larger fill line and repeat the calculations. Additional cost of a larger line should be weighed against the possible time savings, keeping in mind that a slow moving pig is likely to hang up.

Draining

For draining, it is even more important that excessive pressure drops be avoided. An undersized drain line not only wastes time, but if the water discharge valve is wide open and original rate of flow cannot be maintained, there is chance that the pig's position could be lost. It would be necessary in that case to pinch the water control valve until the water jet

TABLE 2
Drain pig speed and water discharge rate.

Main Size	Water Discharge Size	LENGTH OF WATER JET - FEET 1 Pig Speed fpm	1 Flow Rate cfm	2 Pig Speed fpm	2 Flow Rate cfm	3 Pig Speed fpm	3 Flow Rate cfm	4 Pig Speed fpm	4 Flow Rate cfm	5 Pig Speed fpm	5 Flow Rate cfm	6 Pig Speed fpm	6 Flow Rate cfm
4"	2"	60	6	121	11	181	17	242	22				
6"	2"	26	6	52	11	79	17	105	22	131	28	157	35
	3"	60	13	120	26	181	38	241	51				
8"	2"	15	6	31	11	46	17	61	22	77	28	92	35
	3"	35	13	70	26	105	38	140	51	175	64	210	77
	4"	61	22	122	44	183	67	245	89				
10"	2"	10	6	19	11	29	17	39	22	48	28	58	35
	3"	22	13	44	26	66	38	88	51	110	64	132	77
	4"	39	22	77	44	116	67	154	89	193	112	231	134
	6"	88	51	177	102	265	154						
12"	2"	7	6	14	11	21	17	27	22	34	28	41	35
	3"	16	13	31	26	47	38	63	51	78	64	94	77
	4"	27	22	54	44	82	67	109	89	136	112	163	134
	6"	63	51	125	102	188	154	251	204				
16"	2"	4	6	9	11	13	17	17	22	21	28	26	35
	3"	10	13	20	26	29	38	39	51	49	64	59	77
	4"	17	22	34	44	51	67	68	89	85	112	102	134
	6"	39	51	78	102	117	154	157	204	196	256	235	308
	8"	67	89	134	175	201	262	268	351				

TABLE 3
Pressure drop in water lines due to friction.

Flow Rate cfm	PRESSURE DROP PER FOOT - P.S.I. HOSE 2½"	HOSE 4"	STEEL PIPE 2"	3"	4"	6"	8"	10"	12"
6	.008	.001	.015	.002	.001				
11	.033	.003	.061	.008	.002				
13	.043	.003	.079	.010	.002				
17	.075	.005	.136	.018	.004	.001			
22	.133	.011	.243	.031	.008	.001			
26	.174	.013	.317	.041	.010	.001			
28	.203	.017	.372	.048	.012	.001			
35	.294	.023	.538	.069	.017	.002	.001		
38	.387	.030	.709	.091	.022	.003	.001		
44	.525	.040	.960	.123	.030	.003	.001		
51	.690	.053	1.27	.162	.040	.004	.001		
64	1.03	.083	1.97	.252	.062	.007	.002	.001	
67	1.18	.091	2.16	.276	.068	.008	.002	.001	
77	1.56	.119	2.84	.364	.089	.010	.003	.001	
89	2.10	.161	3.83	.491	.121	.013	.004	.001	.001
102	2.78	.213	5.09	.651	.160	.018	.005	.002	.001
112	3.30	.253	6.03	.773	.190	.021	.006	.002	.001
134	4.76	.363	8.70	1.11	.273	.030	.009	.003	.001
154	6.24	.477		1.46	.359	.040	.012	.004	.002
175		.623		1.91	.468	.052	.015	.005	.002
204		.850		2.60	.639	.060	.021	.007	.003
256		1.33		4.01	.997	.111	.033	.010	.005
262		1.40			1.05	.117	.034	.011	.005
308		1.91			1.43	.160	.047	.015	.007
351		2.49			1.87	.208	.061	.019	.008

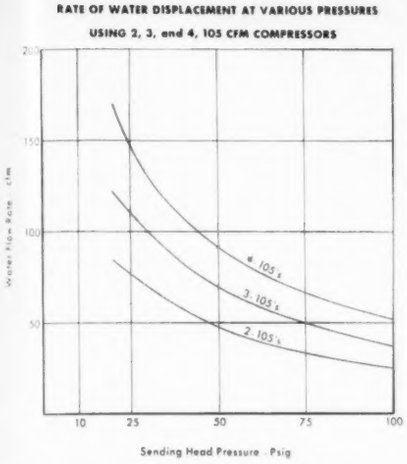


Fig. 2. Curves show maximum rate at which water can be discharged from line using two, three, or four 105 cfm compressors pumping against different sending head pressures.

strikes the next even footmark, carefully noting the time, and establishing a new rate of speed. It is better if the same speed can be maintained throughout the run. Sizing of the drain line is accomplished as follows:

1. From Table 2, determine the cu ft per min of water flow necessary to produce a pig speed of at least 180 fpm. Note corresponding drain line size.

2. Determine total pressure drop at this flow rate from sending head to end of water discharge line. This is done by multiplying appropriate figures from Table 3 by length of main and by equivalent length of drain line (add 25 ft to drain length to allow for fittings).

3. To this loss add 4 psi for each pig and maximum pressure required to overcome the head of water (the pressure difference between the bottom and the top of the greatest over-all upward slope). This total is roughly the pressure required in the sending head to drain the line at the selected rate.

If air or gas pressure greater than calculated above is not available, it is necessary to either select a larger drain size or accept a slower pig speed. The choice will depend upon whether or not the time savings, and perhaps better cleanout, is considered worth the additional cost of the larger drain.

If the pressure required in the sending head is 90 psig or less, air may be used to displace the water. For larger size mains, however, the number of compressors required to maintain a reasonable pig speed may be prohibitive.

Fig. 2 shows the maximum rate at which water can be discharged using two, three, and four 105-cfm compressors pumping against different sending head pressures. To prevent excessive pressure drop between the receivers and the sending head, each compressor hose should be at least ¾-in. diameter and not over 50 ft long (never use "lead" hose). They should be connected through a manifold that is at least 2-in. diameter and as short as possible. One compressor should not normally be used alone because engine failure could mean complete shutdown of the operation. Two 210-cfm compressors will produce as much air as four 105-cfm's, but will have four times as much pressure loss through each hose. Therefore, each 210-cfm compressor should have at least two hoses from the receiver.

If pressure or volume requirements necessitate use of gas, the lead-in line should be at least 1-in. for 4 and 6-in. mains and at least 2-in. for 8-in. and larger mains in order to keep the pressure drop between the supply main and the sending head insignificant.

If pressure and volume requirements can be met with either gas or air, the decision as to which to use should include the following considerations:

1. Gas will either have to be purged from the line with nitrogen before the tie-in is made or a controlled fire tie-in is necessary.
2. Rental costs for the number of compressors required may be considerable.
3. Steady running of several compressors for some time may present a public relations problem.
4. Blowing of gas from the receiving head may be hazardous.

Gas and Air Testing

Lines can be tested by air or gas in their entirety, or tested in sections, using valves in the line to accomplish the sectional spacing.

If gas is used as a test medium, the line should be first cleaned and purged. Cleaning is accomplished by running a pig or pigs as necessary.

When a main that has been full of air is placed in service, the air in it can be safely displaced with gas provided that a moderately rapid and continuous flow of gas is introduced at one end of the line and air is vented out the other end. Gas flow should be continued without interruption until the vented gas is free of air. An oxygen end-point apparatus or similar device is used to determine this. The vent should then be closed.

When air or gas is put into the line to start the filling operation, the test media should be heavily odorized to facilitate leakage testing.

If the test is made with air, and the line is sectionalized, the high pressure air should be moved to the next section following completion of testing, and so on as the test progresses. This procedure is recommended because of the time involved in pressuring up an individual section with portable air compressor equipment.

After the line is pressured with either air or gas, sufficient time should be allowed to permit stabilization of pressure and temperature in the section under test. The pressuring operation should be conducted so that the shut-in line is allowed to stand overnight before the actual test period is begun.

Temperature should be determined at the beginning and end of the test and at regular intervals during the test. Temperatures should be read to the nearest one-half degree F (0.5 F) with accurate glass stem mercurial thermometers located near the deadweight gage and at other locations if advisable. The thermometer may be inserted into a thermometer well located in the pipe, or the bulb of the thermometer may be placed in contact with the outside earth covered pipe wall.

Where difference in pipe temperature at beginning and end of test exceeds one-half degree F (0.5 F), the absolute pressure at end of test is adjusted by a multiplying factor equal to:

$$\frac{\text{Temp. at beginning of test} + 460}{\text{Temp. at end of test} + 460}$$

After line has been under pressure for sufficient time to stabilize pressure and temperature, all connections to the test section should be checked for leakage and, if necessary, blind plated.

Line should be held under stabilized test pressure and temperature for minimum period of 24 hours.

How to Estimate Volume Of Blowdown

$$Q = D^2 P$$

Where:

Q = Volume of gas in Mcf per hour at 14.9 psia, 60 F, and 0.60 sp. gr.

D = Diameter of opening in inches

P = absolute pressure (psia) near opening

How To Estimate Time and Acceptable Pressure Loss In Air or Gas Testing

$$T_H = \frac{3 \times D^2 \times L}{P_1}$$

Where:

T_H = Time necessary for accurate test in hours

D = Internal diameter of pipe, inches

L = Length of pipe in miles

P_1 = Initial test pressure in psig

$$P_d = \frac{T_H \times P_1}{D \times 949}$$

Where:

P_d = Maximum pressure loss for tight pipe

T_H = Test time

D = Internal diameter of pipe, inches

P_1 = Initial test pressure in psig

(Correction must also be made for temperature variations.)

PREVENTING LEAK-REPAIRS BY PREVENTING THE LEAK

The cast iron pipe gas main you see at the left will handle a mixed manufactured and natural gas at normal pressure for a large gas utility. You will note that the crew is assembling the joints *before* placing the pipe in its trench.

This utility has been installing cast iron pipe in this manner for years. They have never had a leak. Possibly, they may never have one.

The easy-to-assemble mechanical joint, a standout cast iron pipe feature, seals so tightly that, under normal distribution pressures, many gas utilities look to cast iron pipe as the "ounce of leak-prevention that's worth a pound of cure."

That's the remarkable thing about cast iron pipe: it rarely needs attention after installation. In fact, 62 American cities are still using cast iron gas mains that were installed over a century ago.

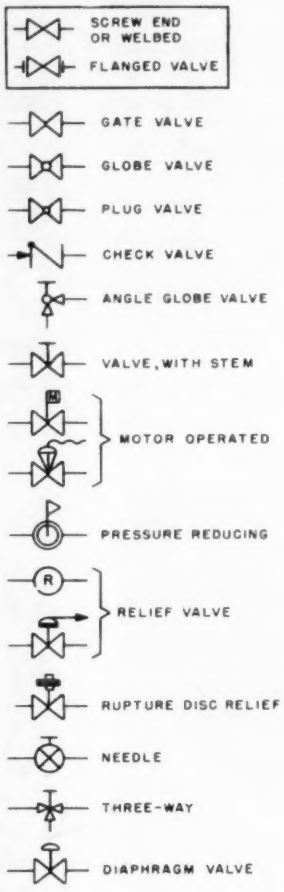
CAST IRON PIPE RESEARCH ASSOCIATION
Thos. F. Wolfe, Managing Director,
3440 Prudential Plaza, Chicago 1, Illinois

CAST IRON PIPE
THE MARK OF THE 100-YEAR PIPE

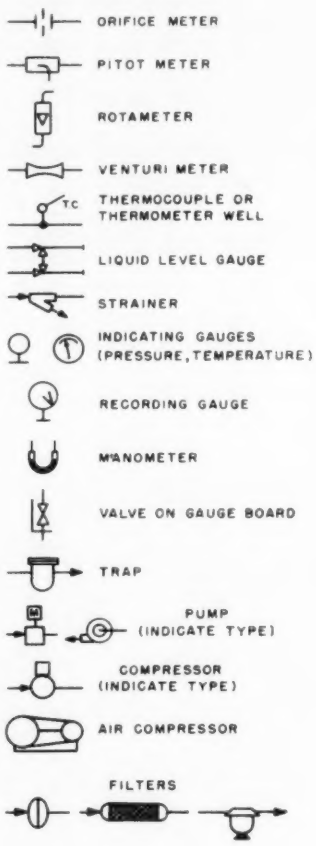
GRAPHIC SYMBOLS

PIPING, FITTINGS, CONTROLS, ACCESSORIES

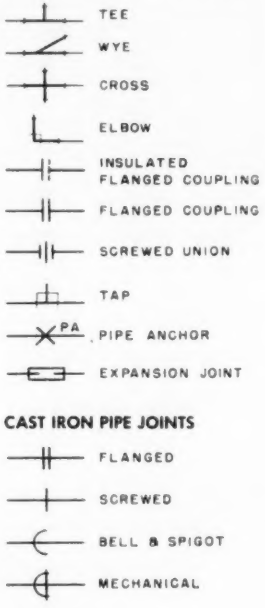
VALVES



MISCELLANEOUS



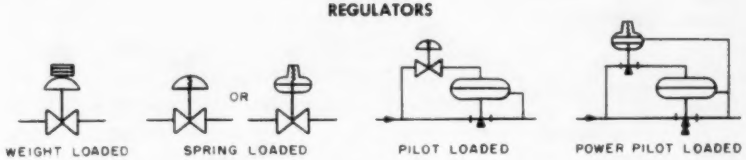
PIPE FITTINGS, CONNECTIONS



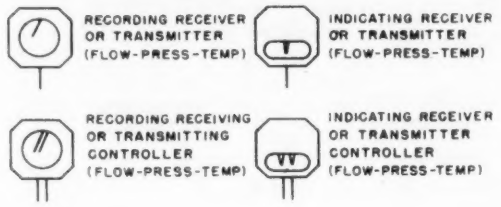
CAST IRON PIPE JOINTS

GAS METERS

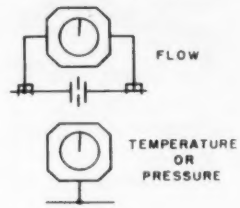
REGULATORS



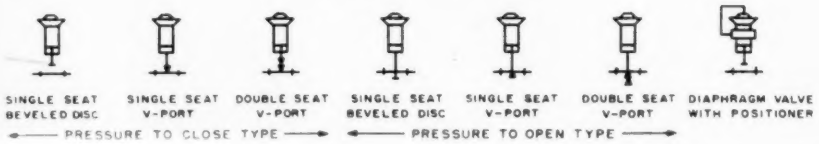
CONTROL INSTRUMENTS


RECORDING RECEIVER OR TRANSMITTER (FLOW-PRESS-TEMP)
INDICATING RECEIVER OR TRANSMITTER (FLOW-PRESS-TEMP)
RECORDING RECEIVING OR TRANSMITTING CONTROLLER (FLOW-PRESS-TEMP)
INDICATING RECEIVER OR TRANSMITTER CONTROLLER (FLOW-PRESS-TEMP)

TYPICAL RECORDER AND TRANSMITTER APPLICATIONS



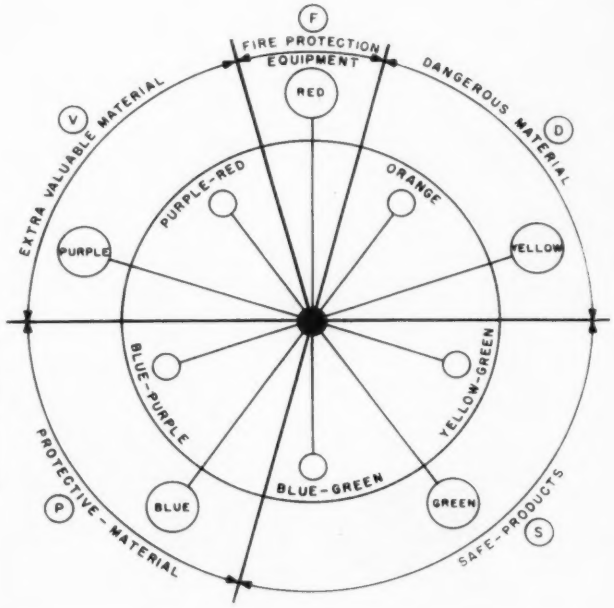
OTHER DIAPHRAGM VALVE SYMBOLS



COLOR CODE FOR PIPING SYSTEMS

CLASS	COLOR
F	RED
D	YELLOW OR ORANGE
S	GREEN (OR WHITE, BLACK, GRAY OR ALUMINUM)
P	BRIGHT BLUE
V	DEEP PURPLE

COLOR CODE FOR PIPING SYSTEMS



Basic Weld Symbols

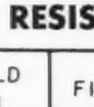
ARC AND GAS WELDS

TYPE OF WELD							
BEAD	FILLET	PLUG OR SLOT	GROOVE				
			SQUARE	V	BEVEL	U	J

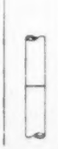
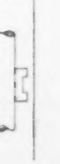
SUPPLEMENTARY SYMBOLS

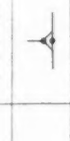
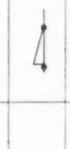
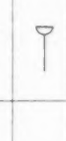
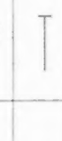
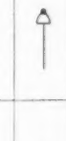
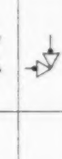
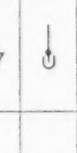
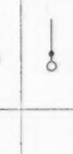
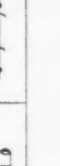
TYPE OF WELD			
SPOT	PROJECTION	SEAM	FLASH OR UPSET

RESISTANCE WELDS

WELD ALL AROUND	FIELD WELD	CONTOUR	
		FLUSH	CONVEX
			

SYMBOLS FOR CONNECTIONS IN WELDED PIPING SYSTEMS

Two-line	Single-line	Joint or Fitting
		Welded Line Joint—Field Tie-in Weld
		Welded Line Joint—Shop or Field
		Nipple
		Welding Neck Flange
		Lap Flange with Lap Welding Nipple
		Welded Slip-on Flange
		Fabricated Flange
		90° Welding Elbow
		45° Welding Elbow
		180° Welding Elbow
		Standard Pipe Bend
		4-Piece 90° Welded Turn
		4-Piece 90° Semi-Welded Turn
		Semi-Welded Offset
		Welded Tee
		Welding Elbow Sweep Tee
		Pipe Bend Sweep Tee
		Welded Turn Sweep Tee
		Anchor

Two-line	Single-line	Joint or Fitting
		Welding Tee
		Welding Outlet
		Welded Lateral
		Welded Y
		Concentric Welding Reducer
		Eccentric Welding Reducer
		Concentric Welded Reducer
		Eccentric Welded Reducer
		Swaged Reducer
		Orange Peel Head
		Blunt Head
		Square Head
		Formed Head
		Welding Head
		Welding End Valve
		Welding End Angle Valve
		Down-Turn in Line
		Up-Turn in Line
		Offset in Line

Safety for Welders in Distribution Operations

Both arc and acetylene welding are hazardous. For this reason, the welder and helper should be familiar with every safety device as well as safe methods for welding gas lines without causing a fire or explosion.

The following discussion is intended as a guide to safety for welders. In addition to these items, welders and helpers should be constantly alert to any and all hazards not presented here and eliminate and/or report them.

- Never allow oil or grease on or near any oxygen equipment. To do so may cause fire or a violent explosion.
- Oxygen cylinders contain oxygen and should never be referred to as "air."
- Acetylene cylinders contain acetylene and should never be referred to as "gas."
- Oxygen and acetylene cylinders should be handled with care. When cylinders are being moved, except in proper carts or racks, gages should be removed and caps must be placed on oxygen valves.
- Acetylene cylinders are used and stored in an upright position. These cylinders contain acetone, a liquid, that will flow into welding equipment if the cylinders are used in a horizontal position.
- "T" handles should be kept in a handy place so that acetylene may be readily shut off in case of fire.
- Never open an acetylene tank valve more than 1½ turns. The stems can be screwed out, causing possible serious damage from acetone freezing, as well as a serious fire hazard.
- Do not cut or weld within 3 ft of oxygen or acetylene cylinders.
- Welders and helpers should wear proper eye protection at all times when cutting, welding, or observing a lighted torch.
- Welders should not weld or cut with a torch any barrel, gas tank, or closed top vessel that has contained gasoline, fuel oil, or any other explosive material until it has been made safe by purging with carbon dioxide, properly rinsed with carbon tetrachloride, boiled out with chemicals or steam, or by other approved procedures to prevent internal explosion.
- A vent hole should be made in any closed container before welding is begun.
- Helpers should stay with welder at all times when welder is working. If he is not needed in a bellhole or ditch, he should remain on top of excavation, attend the welder, and watch for fire, cave-ins, etc.
- Before a torch is used in ditch or bellhole where gas has been or may be present, the ditch or bellhole should be "flashed."

Sounding

- If, after cutting, welding, or performing any operation requiring fire in a ditch or bellhole, it is necessary to perform any operations that require the release of gas, the following "sounding" precautions should be taken to prevent fire:

  a. Open acetylene valve on torch as if to light it.
  b. DO NOT LIGHT TORCH.
  c. Go over all four walls and especially under the edge of pavement around edge of the hole if pavement is present.
  d. Where gas mains have been leaking, even though pressure of main has been cut off, it is possible to have enough gas in the ground to maintain a pilot light for many hours, if it had become accidentally lighted while using fire in the hole.
  e. If such a pilot is present, the torch will be lighted by it, indicating gas is present.
  f. After source of flame has been located and repaired or corrected, the entire sounding procedure should be repeated. After this procedure has been followed, and no flames found, gas may be turned loose in the bellhole.

- While welding overhead or "tieing-in" or doing any welding that leaves an ear exposed to sparks and flying weld metal, welder should wear ear plugs.
- When mains are cut, open ends should be closed immediately with a suitable stopper to prevent entrance of air.
- If cut is made in preparation for removal of a section of pipe, first cut should be taped immediately upon completion, to prevent entrance of air while second cut is being made.

  Upon completion of second cut, section should be removed at once and suitable stoppers used, or the second cut should be taped.
- Extreme care should be used when working on a gas main that is open at two places. It should be remembered that air could enter the line at one opening and escape at the other, allowing the formation of an explosive mixture.
- During course of construction, it is sometimes necessary to tie an unfinished main extension or service into a live main with a valve between them and leave this arrangement overnight without purging. Before starting to weld to the end of this extension, the welder should lower a lighted torch to the end of the extension to explode any possible explosive mixture that may have accumulated during the night due to a leaky valve. All employees should be in the clear.
- Do not use oxygen in place of air for cleaning or testing. Never use oxygen to blow off clothing.
- When necessary to do cutting or welding in an underground vault, employee responsible for such vaults should be notified. He should arrange for proper clearance and ventilation and should supervise work while in progress.
- Vaults should never be "flashed" with a lighted torch.

Personal Protection

- Protective clothing worn by the welder should include a non-flammable skull cap, flameproof gauntlet type gloves, high top shoes, cuffless trousers, and special equipment such as flameproof capes, aprons, and arm and leg covers as required to protect against burns. Sleeves should be kept rolled down and collars buttoned while welding.
- Proper shade of filter lenses should always be used in the welder's helmet or goggles. A clear lens should always be placed in the helmet or goggles immediately in front of the filter lens to protect the filter lens against pitting. Acetylene goggles should not be lighter than shade 3 and arc welding lenses should not be lighter than shade 8.
- Helpers and any other workmen assisting the welder should also wear adequate protective clothing and equipment to protect against radiation burns and flying sparks and slag.
- Welder is responsible for protecting others in the area from radiation burns by placing an adequate curtain or shield about his work.
- A dry chemical type fire extinguisher of at least 20-lb capacity should be available within a few feet of the welder in case of fire.
- Before igniting his torch, welder should make certain that there are no combustible materials in the immediate area.
- The best body position should be decided upon to minimize the hazard of falling or flying sparks and slag.
- Upon completion, hot welds should be marked or covered to prevent someone from touching them after the welder has left.

* * *

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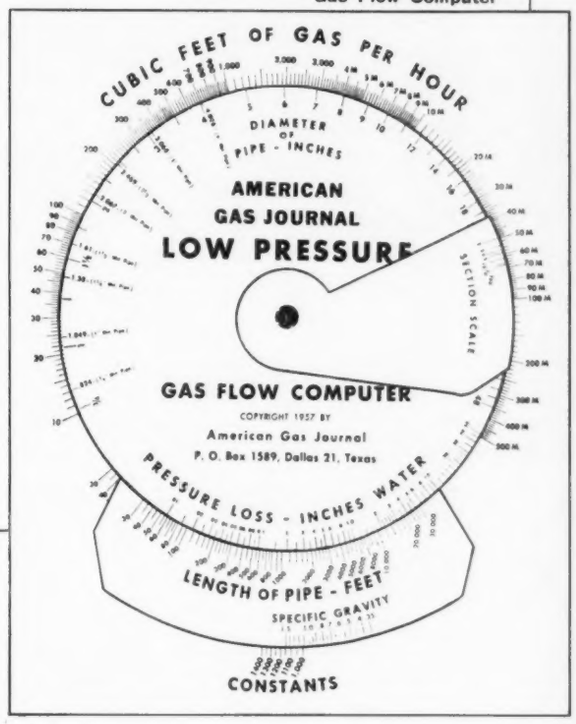
GAS FLOW COMPUTERS

American Gas Journal

LOW PRESSURE

Gas Flow Computer



For LOW Pressures

Cubic feet of gas per hour . . . . . 10 to 500M
Pipe diameters . . . . . 3/4-in. to 48-in.
Pressure loss (inches) . . . . . 0.1 to 50
Specific gravities . . . . . .35 to 1.5
Constants . . . . . 1000 to 1400
Pipe length (feet) . . . . . 30 to 30,000

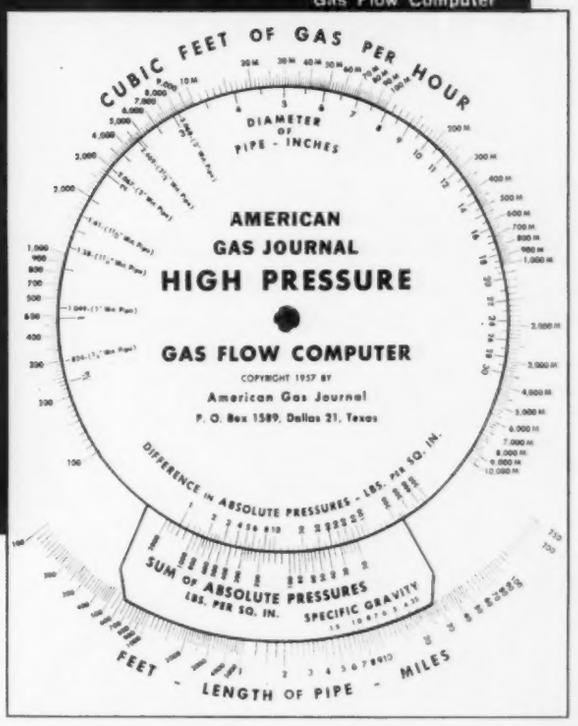
For HIGH Pressures

Cubic feet of gas per hour . . . . . 100 to 10,000M
Pipe diameters . . . . . 3/4-in. to 30-in.
Difference in absolute pressure to . . . . . 500 psi.
Sum of absolute pressures . . . . . 20 to 2,000 psi.
Specific gravities . . . . . .35 to 1.5
Pipe length (feet) . . . . . 100 to 5,000
Pipe lengths (miles) . . . . . 1 to 250

American Gas Journal

HIGH PRESSURE

Gas Flow Computer



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AMERICAN GAS JOURNAL

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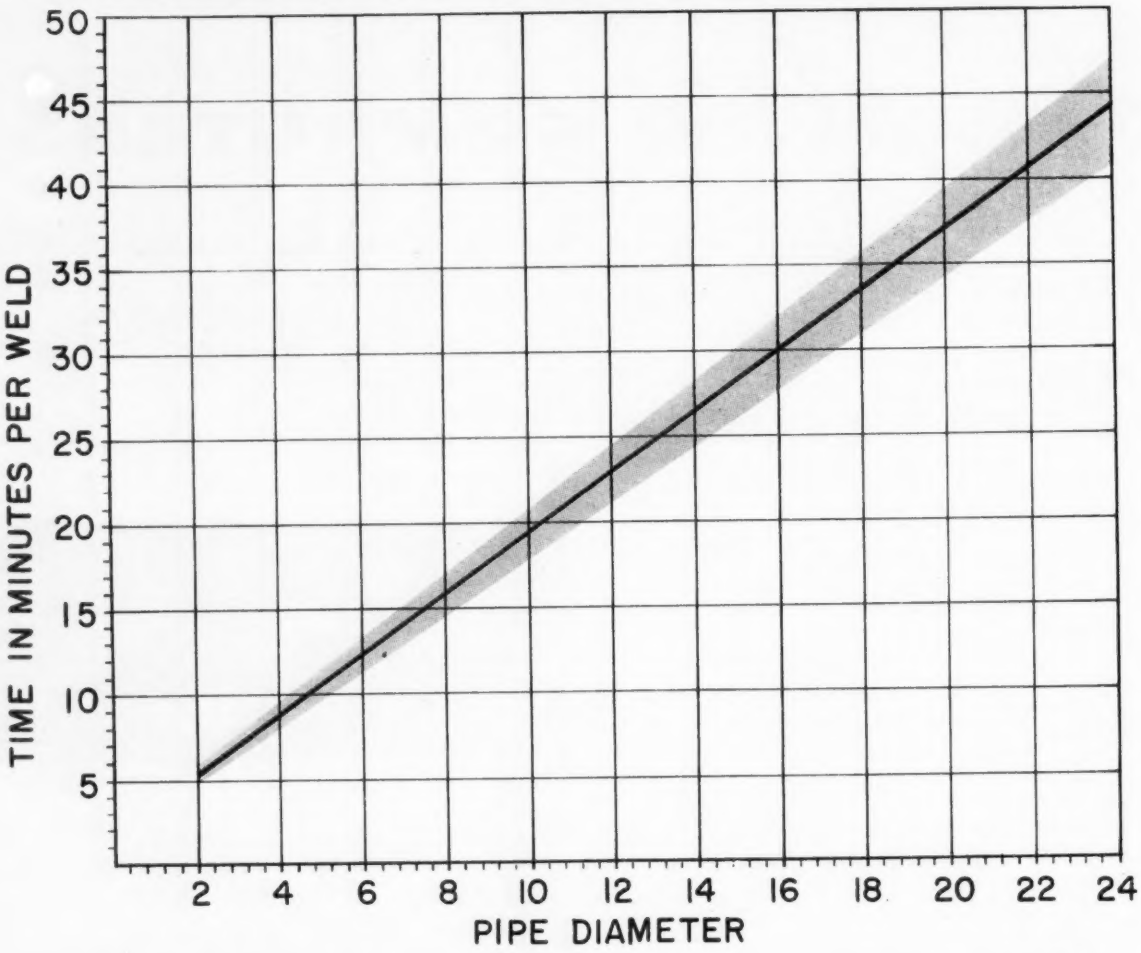
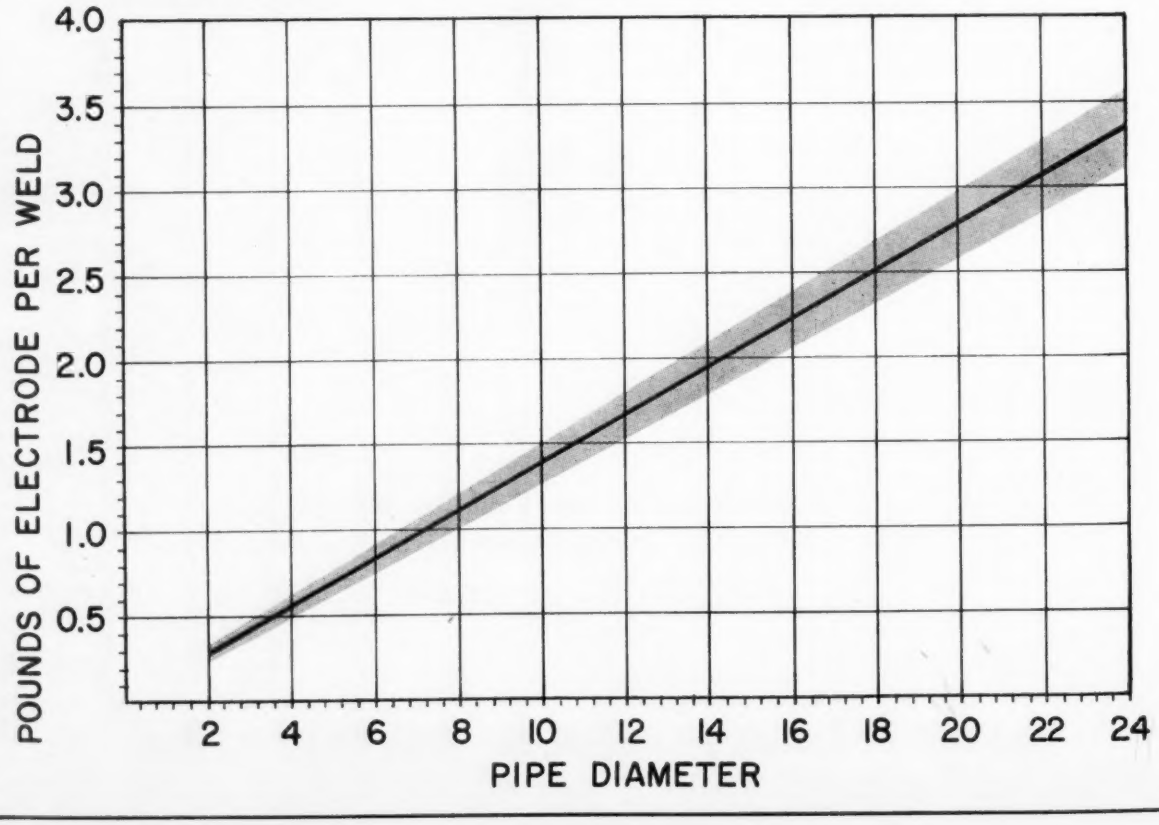
Estimating Data: Welding Time Per Weld



Estimating Data: Electrode Consumed Per Weld



Backfilling and Soil Stabilization

A stable backfill is an important consideration in gas main construction because:

1. *A stable backfill forms the base for surface restoration.*
2. *A stable backfill protects underground structures from mechanical failure.*

Surface Restoration

Each surface restoration class (Table 1), like other structures, must be supported by a foundation. If the foundation fails through settlement, the surface restoration is no longer serviceable and must be repaired. The surface area involved may be a single street opening, or may be several hundred feet of trench. In any event, the responsibility for repair and any damage and/or injury incurred due to settlement of the restored area must be borne by the agency making the excavation.

Modern day, uncongested traffic flow demands that closure and surface restoration keep a pace with construction. This can and does in some cases apply even if the work is not completed in a specific interval of time. Peak traffic flows may require temporary bridging. Closure may be, simply, a steel bridge over the excavation or a temporary backfill to be re-excavated, or a permanent backfill with temporary surfacing, or permanent backfill with a permanent surface

It is usually found that it makes little or no difference whether closure and surfacing is temporary, partially temporary, or permanent in nature. The community imposes the same rigid set of standards. The term "temporary" is limited to the restoration surface, since by any service or economic standard, a temporary backfill does not exist.

Large cities usually perform their own surface restoration by means of city crews or contractors. Cost of permits for excavation includes the cost of surface restoration and varies according to class and type of services desired. Restoration services offered by cities are of the following types:

1. **Complete restoration.** City forces excavating and disposing of temporary surface, placing a concrete base or other base adequate for the purpose, and installing the pavement complete.
2. **Surface restoration.** Concrete base, or other base adequate for the purpose has been installed by contractor forces in accordance with specifications. Paving surface to be restored by city forces.
3. **Special surface restoration.** Permittee has installed a concrete base and has made temporary surface restoration. Concrete base is uniformly placed 2½-in. below street surface. Surface is a temporary bituminous concrete which will be allowed to remain in place, serving as a binder for final sheet asphalt surface that will be installed by the city.
4. **Inspection.** The entire restoration, both base and surface, has been performed by permittee, under the direction and to the satisfaction of city officials.
5. **"Force Account" or "Cost Plus."**

Smaller communities not having these services are entirely dependent upon the excavator for the performance of surface restoration. The only requirement being adherence to local specifications and applying the same class of surface and base as initially found. Exceptions being that Class 2 pavements (brick, granite, durex, woodblock) would be replaced by concrete.

In localities where average temperatures of less than 40F occur, production of hot mix bituminous concrete is curtailed. A cold applied, pressure sensitive bituminous concrete is substituted and gives satisfactory performance as a temporary and/or permanent surface.

Protection of Underground Structures From Mechanical Failure

Strength is the ability of a pipe to resist, without failure, stress producing forces. Strength considerations are usually taken into account by pipe manufacturers and include provisions for:

1. The effect of a crushing load produced by the weight of the backfill.
2. Variations of the crushing load transmitted to the pipe under different trench conditions.
3. A factor of safety based on hoop stresses resulting from internal pressure and external load.
4. An allowance for corrosion and manufacturing tolerances.

Forces acting upon buried pipe structures are usually termed **"external loads."** External loads are produced by and represent the combined effect of forces originating from:

1. The backfill — (includes soil body forces, soil seepage forces).
2. Surface loads — (includes weight of traffic, weight of structures, sudden impacts.)

External loads are transmitted through the soil environment to the pipe. External loads occur in sufficient magnitude to cause failure unless restricted or resisted.

Fig. 1 represents a typical cross section of a backfill showing a pipe laid in a trench excavation. The terminology used is more or less standard throughout our industry. The section shown applies to trafficked surfaces. For other surfaces the cover would be extended to ground elevation.

The outstanding functional property of a dense backfill is the protection of the pipe from surface loading. The protection is gained through a reduction in the magnitude of an applied external load. The relationship between depth of cover and incremental reduction of external loading **P** is shown in Fig. 2. This relationship represents stress increments due to concentrated point loadings and/or point load approximations. Such a condition would exist for all situations, excluding Class 1 and Class 4 pavements.

The Class 1 and Class 4 pavements are considered as continuous solid load bearing pavements and they represent conditions where stress increments are the results of a distributed boundary loading. This condition is not applicable to the *Boussinesq* equation (Fig. 2A).

It is a common practice to treat distributed boundary loadings by a method known as the 60° approximation (Fig. 2B). Here, surface loadings are assumed to be distributed uniformly over an area $\mathbf{A}_1$.

The loading at any subsequent depth **Z** is assumed to be distributed uniformly over an area $\mathbf{A}_2$. Area $\mathbf{A}_2$ is defined by planes descending from the edges or boundaries of $\mathbf{A}_1$ intersecting a horizontal plane in a 60° angle at depth **Z**. The load increment within these limits at any depth **Z** is the load **P** divided by area $\mathbf{A}_2$. For the usual cover of 3-ft, the stress reduction is not significant and no accuracy is lost

TABLE 1. Classification of Pavements

Class 1: Concrete.
Class 2: Brick, granite, Durax.
Class 3: Asphalt, other bituminous pavements on concrete base, boulder, and racked limestone, if so classed, or machine paved bituminous paving irrespective of kind of base.
Class 4: Bituminous pavements on stone base. Surface treated or oiled macadam.
Class 5: Low type pavements (plain macadam, gravel, etc., not surface treated or oiled).
Class 6: Sidewalks, cement, brick, flagstone, etc.
Class 7: Concrete base only or any similar material used as a base incident to the resurfacing of a street under contract or by city forces.

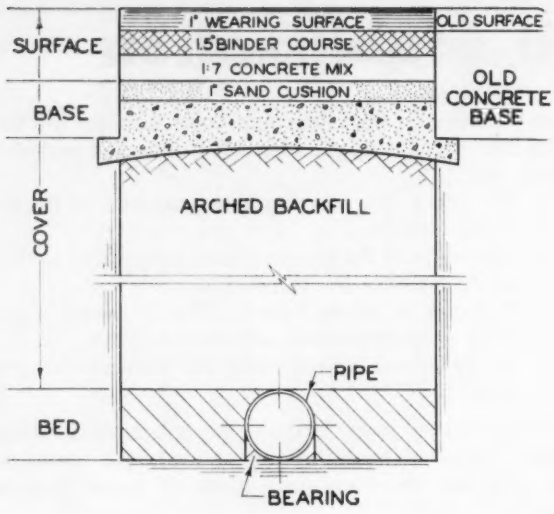


FIG. 1. Section through backfill.

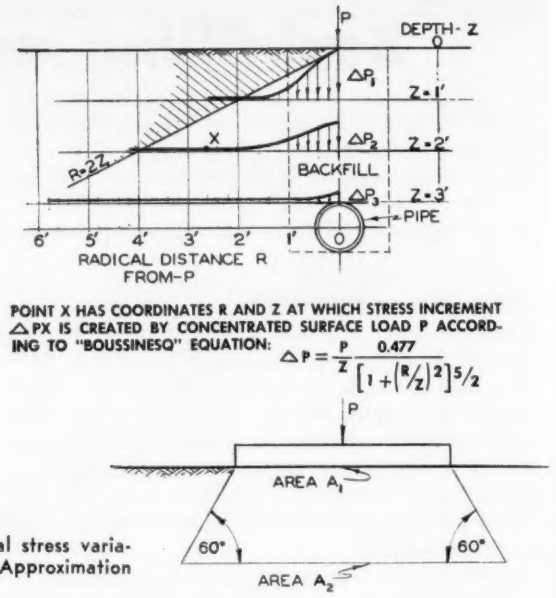


FIG. 2. (Top) Vertical and horizontal stress variations due to point load. (Bottom) 60° Approximation distributed loading.

if the stress distribution is simply the load **P** divided by the area $\mathbf{A}_1$.

The *Boussinesq* and the *60° Approximation* equations are independent of the nature of the soil. If the external loading, at any depth, exceeds the ultimate soil bearing capacity at that depth, soil settlement will occur having the possible consequence of pipe failure.

External loads transmitted through the soil to the pipe surface are resisted by pipe deflection, pipe distortion, and trench bottom conditions. The importance of the load bearing capacity of the trench and improper bearing between trench and bottom of the pipe cannot be over-emphasized. *Low soil bearing values between pipe and trench invite pipe deflection and pipe failure.*

Soil body forces are the vertical forces at any point in a soil formation. The forces result from the thickness and unit weight of the overlaying material. These forces increase in direct proportions with depth and tend to deform or compress the underlying soil stratum.

Soil seepage forces are the multi-directional forces resulting from the movement of gravitational water through the soil. As water moves, a drag is exerted on each soil particle, the magnitude of which is proportional to velocity of flow.

Properties of Soil

A very loose but adequate definition of soil would be "any unconsolidated material that can be excavated with pick and shovel." This certainly is an all inclusive definition and could equally be applied to small glacial boulders, swamp slime, and refuse of the city dump. A more exacting concept is a "heterogeneous," chaotic mixture of almost anything.

It is obvious that soil cannot be treated or analyzed by simple handbook data; soil must be recognized and treated as a unique substance requiring special study and special consideration.

Soil is universally classified by texture. Texture is a reflection of particle size and shape. There are three texture classification categories:

1. *Sands;* 2. *Silts;* 3. *Clays*

It is convenient to express all other soil mixtures in terms of the sands, the silts, and the clays. Rock and/or organic products are not considered primary soil components. Fig. 3 is a triangular method of classification developed by the U. S. Corps of Engineers whereby the boundaries of all possible soil admixtures are established.

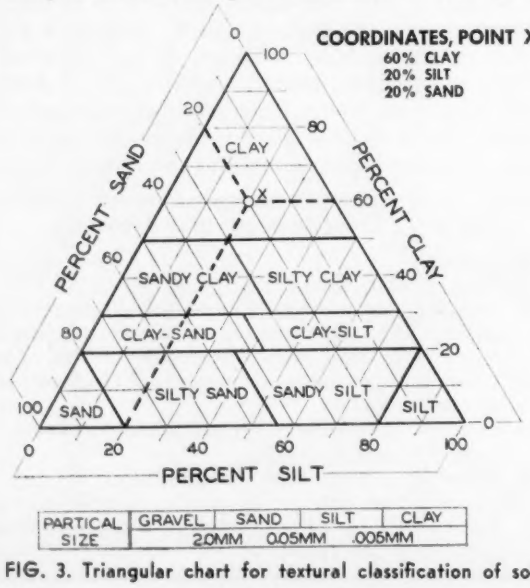


FIG. 3. Triangular chart for textural classification of soils.

The mineral sands, silts, and clays represent the solid phase of three phase soil relationship, the remaining two phases being gaseous (air) and water. This three phase relationship is illustrated by Fig. 4.

The final combination of air, solid, and water determines soil structure. Soil structures can be placed in three basic categories.

1. **Single grained.** Typical of bulky particles exhibiting particle to particle contact (Fig. 5A), similar to the stacking of apples by the grocer either as (a) loose, that is one apple placed directly on top of its neighbor or (b) dense, one apple placed in the valley formed by its adjoining neighbors.

2. **Honeycombed.** Typical of the fine grained, bulky particles laid down in the still waters (Fig. 5B), the particles of which form arch-like chains that remain in place during settling as opposed to rolling or moving to a more dense and more stable position. Honeycombed structure is characterized by a high void ratio, a relatively stable structure, but extremely sensitive to shock, with break downs occurring suddenly as chain-like reactions converting the mix to a heavy fluid-like liquid.

3. **Flocculent.** Typical of the extremely fine grained soils. Structure originates from colloidal suspensions (Fig. 5C). Soil particles have large surface to thickness ratios and are charged electrically — settlement either edge-to-surface contact in flocs or parallel particle-to-particle. The distinguish-

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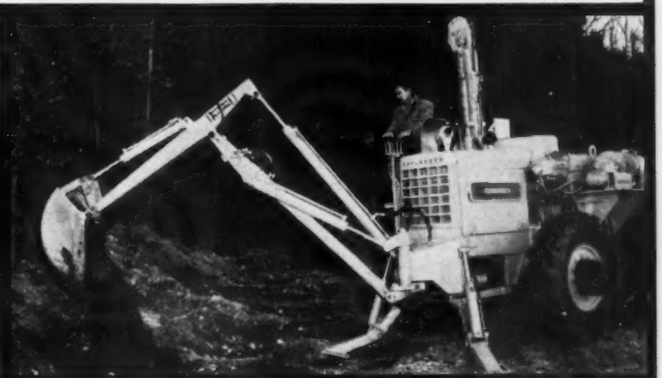

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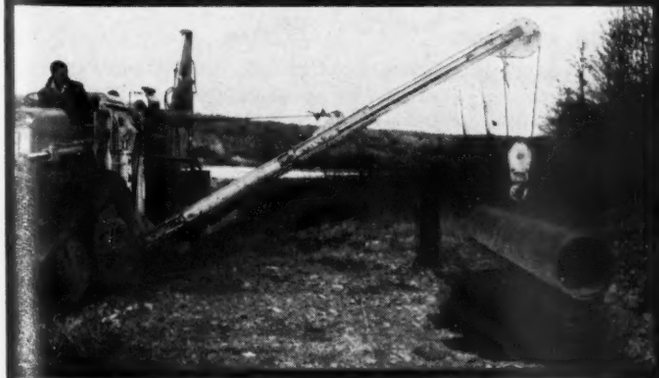

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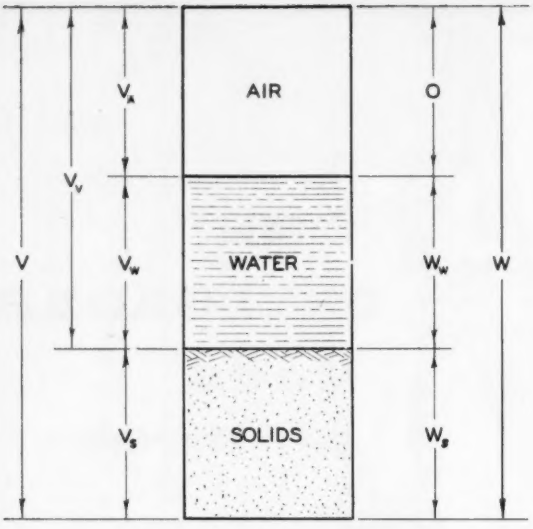

FIG. 4. Soil phase relationships.

ing feature of this structure is a weak but continuous open framework with relatively large void passage.

Many natural soils occur in the three basic structures. Other soils occur in more complex structures similar to Fig. 6. In the complex mixtures, structure — together with particle size — determines the ultimate behavior of the soil.

For example, if the solid phase is large grained, having particles contacting each other and other smaller cohesive particles occupying the voids, the soil will behave as if it were composed entirely of large grained material (Fig. 6A).

On the other hand, if the coarser particles are suspended in a clay matrix and are prevented from having surface to surface contact by the matrix (Fig. 6B), the soil will behave as if it were composed of entirely fine particles.

Other noteworthy properties of soil that are deserving of consideration in this limited space are *soil permeability* and *soil strength*.

The void or open spaces in the three phase soil relationship, occupied by all of the air and some of the water (we cannot say all of the water for reason that will be seen in a later section) are termed the voids. Soil voids are not isolated spaces. Soil voids are interconnected and form passages through which gravitational water can flow. The soils' ability

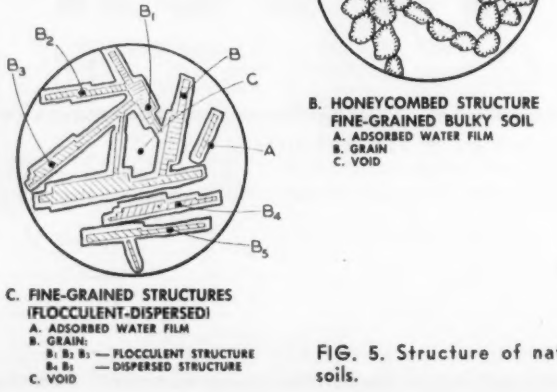

FIG. 5. Structure of natural soils.

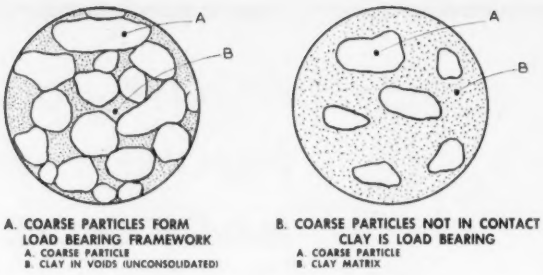

FIG. 6. Structure of mixed soils.

to permit such water flow is a measure of its *permeability*. Soil permeability is important since it determines the time rate at which the soil reaches its ultimate compression.

It has been stated several times that soil is a combination of three distinct phases—solid, liquid, gaseous. The relationships between the three phases are continuously changing. Soil, unlike other more familiar engineering materials, is not a solid and is not a liquid. It is necessary to recognize that *strength* at a point in the soil formation is not singularly dependent upon the properties of one material; rather, soil strength is determined by the property of more than one material. The influence of these properties varies with time.

Cohesionless soils, which include all of the sands and some of the silts, derive their strength through internal friction between particles. The magnitude and direction of the principal stress acting on a single particle is the resultant stress, formed by the combination of the vertical normal and tangential sheer stress. The oblique angle of the resultant, measured from the normal (vertical), is indicative of the relative magnitude of the resultant stress and, therefore, the ultimate strength. When the value of this angle reaches a maximum, failure will occur. The friction angle of the cohesionless soil is equal to the maximum angle of obliquity of the resultant.

The soils exhibiting cohesion, including all of the clays and some of the silts, do not derive their strength through internal particle friction (particles not in particle to particle contact) but rather, derive their strength through resistance due to cohesion. Cohesion is a property that, like viscous friction, varies with liquid consistency.

Due to the differences in structural arrangements, a fixed relationship between the tangential and normal stresses at failure does not exist. The magnitude of stress at failure is approximately equal to the unit cohesion, regardless of the value of the normal vertical and tangential stress.

Rather than resorting to the unit cohesion as a strength index, it is common practice to correlate strength with unconfined compression test results. An *unconfined compression test* is made simply by applying an axial load to a clay cylinder that has no provision for lateral support.

Soil Moisture

Moisture is always present in soil. The behavior of a soil is largely determined by its moisture content. The two primary sources of soil moisture are:

1. *Capillary rise from the water table.*
2. *Gravitational movement of water through soil voids.*

Moisture from the two primary sources can be termed: 1. *Chemical or molecular.* 2. *Adsorbed.* 3. *Free.*

The term *chemical or molecular* refers to the water that is chemically combined with soil minerals.

The term *adsorbed* refers to the water held immobile on the surfaces of the soil elements.

The term *free water* refers to the water moving through the soil voids under the influence of gravity or pressure differences.

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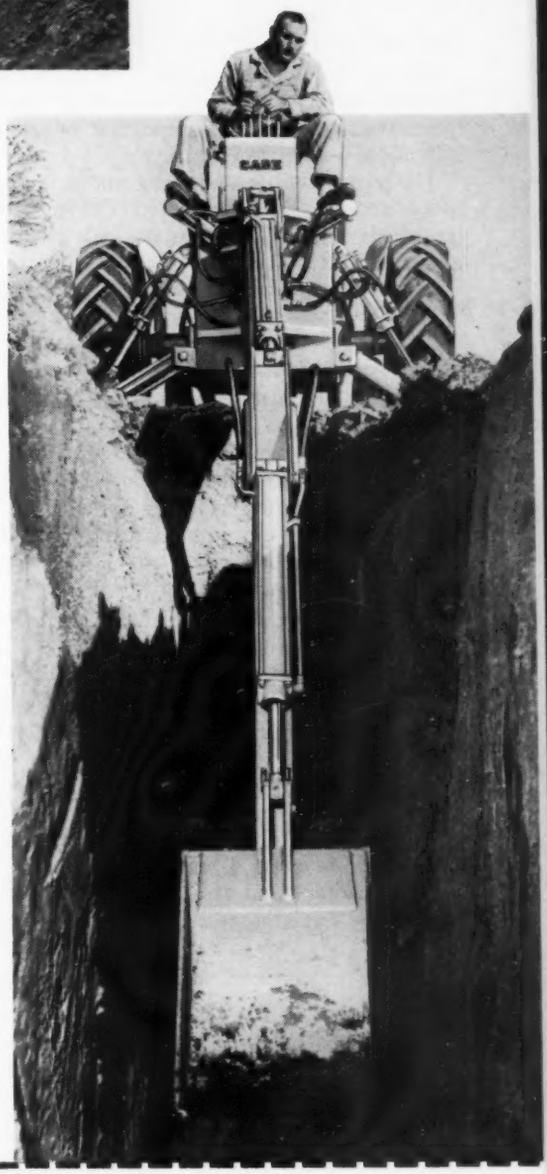

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water film in the behavior of soil, it is necessary to gain a knowledge of its origin.

Soil particles are inherently charged negative. The magnitude of the charge is dependent upon the chemical composition and surface molecular structure of the grains. Molecules of water can be thought of as being polar in nature. Water molecules are attracted to the soil particles where they are held immobile by the surface charge of the particle. The layer of water surrounding the soil particle is termed the adsorbed water film.

Thickness of the adsorbed water film is dependent upon the availability of water in the soil and the magnitude of the surface charge of the soil particle. The layers of water molecules in close proximity to the grain surface assumes the properties of a solid. The more remote layers exhibit the properties of a viscous liquid or glue.

Forces associated with the adsorbed water film play an important role in the determination of physical properties of the fine grained soils but have little effect on the properties of coarser soils.

Soil Stabilization

With a limited but basically adequate knowledge of soil behavior we can now fully appreciate with some degree of understanding the most important of all backfilling considerations — *soil stabilization*.

The term stabilization is used with reference to the various procedures used to improve soil behavior characteristics and represents man's efforts to make soils conform to some minimum standard.

There are two distinct categories of consideration:

1. *Mechanical stabilization.* 2. *Chemical stabilization.*

Mechanical Stabilization

Compaction is the resulting effect when a pressure or force is applied to a soil. In its most general sense, compaction means bringing the soil particles close together, thus increasing the density of the soil. *Density* is a measured weight per unit volume. *Soil density* is the measure of dry weight per unit volume of the soil. Four density variables must be considered.

1. Moisture content.
2. Unit density.
3. Compaction effort.
4. Soil type and gradation.

Moisture has a marked effect in soil density relationships. For a given moisture content, the density varies with the compaction effort (Fig. 7). Compaction effort can vary with type and kind of mechanical compactor chosen, number of passes per backfill layer, speed of forward motion, energy expended. Conversely, at a given compaction effort density can be related with moisture content. At a given moisture content and at a given compaction effort, coarse grained and fine grained soils will respond differently.

On Fig. 7, curve A is a plot showing the *moisture-density relationship at a specific compaction effort*. Curve A represents actual behavior and is usually referred to as the *Proctor* curve. Curve B (Fig. 7) is a plot of the theoretical maximum density or, as it is usually referred to, the *zero air void curve*.

The zero air void curve is theoretical and represents perfect compaction at any given water content. If all the air is expelled from a soil, the soil is 100 percent saturated.

Note that curve B lies above curve A at all times. At the higher moisture contents, the dry densities are low as the water occupies much of the soil volume. At lower water contents the theoretical dry density increases. At the higher moisture contents, the actual and theoretical curves appear to be parallel; at the low moisture contents, however, there is a significant difference. This difference is caused by the very viscous adsorbed water film surrounding the soil particles to the extent that it interferes with particle movement over adjoining particles.

In effect, soil tends to resist compaction. The optimum is represented by a compromise — enough water to act as a lubricant and allow the grains to compact easily but not enough to restrict movement thereby limiting the volume of the soil.

Each soil exhibits an optimum for a given compaction effort. Differences in compaction effort will result in different optimum points (Fig. 8). Generally, the greater the compaction effort the lesser will be the optimum moisture content and the greater the maximum dry density. Optimum moisture is not an inherent property but depends on the method of compaction.

When the water content is relatively high, the inefficiency of the compaction process is readily observed in the field, since the compaction effort tends to displace the soil instead of compressing it. Compaction on the low moisture side is not so obviously inefficient and, actually, the results appear satisfactory and compaction equipment operates with less difficulty to the extent that many operators erroneously tend to prefer this condition.

Fig. 9 relates moisture content with strength for average clays. Unconfined, compressive strength values can be easily obtained in the field using a simple penetrometer.

Soil texture also plays an important role. The foregoing discussion of optimum compaction was descriptive of a fine grained cohesive soil such as clay. Granular or cohesionless soils, the sands, become most dense when their grains assume new positions that reduce the void spaces between them. Pressure is almost useless.

Vibration accompanied by light pressure is most effective. A severe shock or a series of harmonic repetitive shocks produced by impact of a heavy object can increase the density of cohesionless soils at several feet depth. Cohesionless sands slightly moist will exhibit a reduction in sensitivity

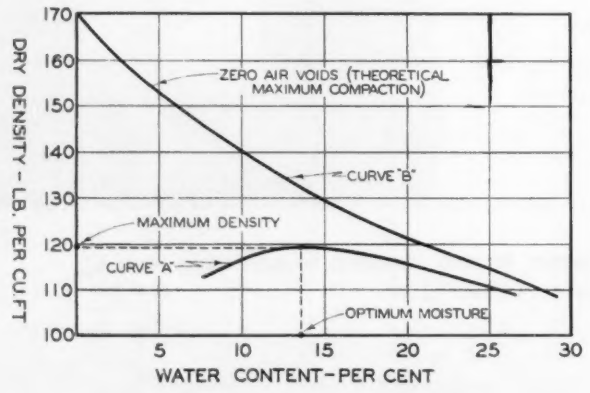


FIG. 7. Moisture-density relationship.

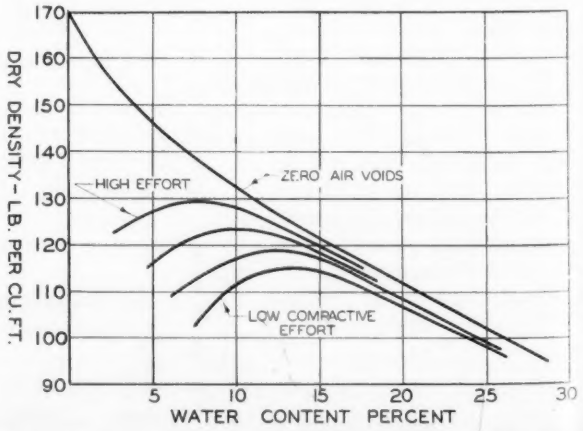


FIG. 8. Effect of compaction effort on moisture-density relationship.

to vibration. Capillary tension acts to restrict free movement of the grains. Complete water saturation, however, will eliminate capillary tension and permit compaction.

Slightly cohesive soils (silts) are more readily compacted by a pressure that squeezes the grains together. If the pressure is too great, the soil will fail in shear, producing a loose backfill. An alternate for slightly cohesive soils that is very effective is complete saturation. During the dry-out, the force due to capillary tension will act as compaction effort.

The disadvantage of flooding should be carefully considered, unless one is **absolutely** sure of the permeability of the parent material. The flooding of backfills where parent soils have poor permeability will result in extremely erratic compaction with soft soupy pockets.

As mentioned before, a cohesive soil must be mechanically stabilized using a compaction effort of considerable magnitude. Mechanical compaction equipment suitable for use in gas construction must be of such design that the equipment can be used in close quarters. Such equipment would include:

1. Hand pneumatic tampers single or in gangs of three — air driven.
2. Gasoline operated soil ramers.
3. Tractor-type backfill tampers.
4. Trench rollers (not widely used).

Control of Compaction

Compaction control is essentially an inspection operation. This includes on the spot observation of the entire backfill procedure to determine:

1. *Suitability of the soil used in backfill* — rock free — remove from construction site and replace if necessary.
2. *Suitability of the backfill soil moisture content.* Add water if too low. Aerate or replace if too high.
3. *Degree of compaction effort required.* Determine thickness of compaction layers, number of passes, speed of advance. Adjust compaction effort in accordance with moisture content.

Other control measures are:

1. *Inclusion of rigid specification for backfilling in contract work.*
2. *Education of work forces in basic soil mechanics.*
3. *Use in field of special equipment to obtain density readings.*

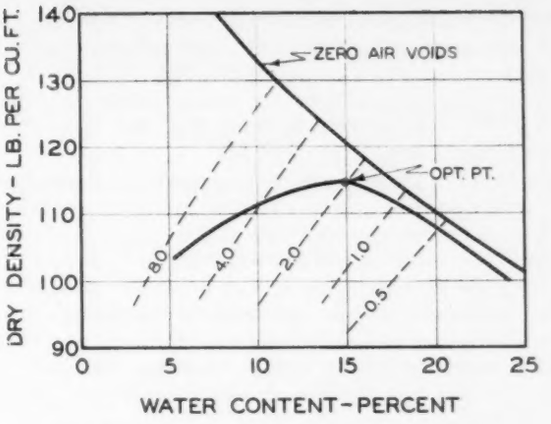
Remedial measures in the event soil conditions are not consistent with good backfill procedures are basically three in number.

1. Change moisture content.
   a. Addition of a water to soil if too low.
   b. Aeration of soil if too high.
2. Change compaction effort.
   a. Addition or deletion of weights.
   b. Increase or decrease number of passes.
   c. Decrease compaction layer thickness.
   d. Decrease forward travel.
3. Change soil.
   a. Carry away all or partial of parent fill and replace from barrow.
   b. Purchase from an outside source a more suitable material.

Chemical Stabilization

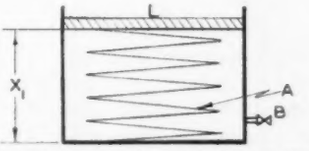
Chemical stabilization is not a separate solution. Its primary use is to make the mechanical methods more lasting. The expense of chemical soil stabilization usually precludes its every day use. Chemical stabilization includes:

1. **Soil cements.** Admixtures of portland cements or fly ash distributed on the surfaces of the backfill in predetermined quantities.

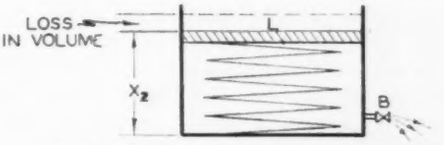


NOTE: DASHED LINES ARE CURVES OF EQUAL COMPRESSIVE STRENGTH IN TONS PER SQ FT.

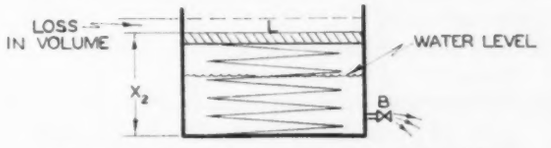
FIG. 9. Relationship of unconfined compressive strength to moisture content and density.



SPRING WITH LOAD "L" IN CLOSE-FITTING CYLINDER OF WATER. SPRING AND WATER SUPPORTS LOAD. SYSTEM AT REST.



WATER ALLOWED TO DRAIN OFF THROUGH VALVE "B." SYSTEM IN MOTION. "L" MOVES TO "X_2," COMPRESSING SPRING "A." SYSTEM AT REST WHEN SPRING SUPPORTS ENTIRE LOAD "L."



ADDITIONAL DRAINAGE OF WATER THROUGH "B" DOES NOT INCREASE LOSS IN SYSTEM VOLUME. "L" REMAINS AT REST, WATER LEVEL DROPS AS SPRING SUPPORTS ENTIRE LOAD.

FIG. 10. Piston and spring analogy illustrating soil consolidation.

2. **Bituminous binders.** Distributed uniformly throughout the soil, decreases sensitivity of soils to water in addition to binding grains.
3. **Water proofing admixtures.** Vinyl resins prevent changes in moisture content.
4. **Deliquescents.** Prevent drying out and soil shrinkage.

Soil Settlement

Settlement of a backfill will always occur if a soil is placed in an excavation in a state of compression that is not at least equal to that of the surrounding parent soil.

Under the compressive action of static loading, natural forces, and under favorable changes in soil structure (but always in a finite period of time) a backfill will tend to seek its ultimate state of compression. Soil under compression will exhibit a change in the volume of soil voids thereby increasing the density of the soil. Soil voids for the most part are filled with free water, the removal of which requires a definite interval of time. The effect of the full compression cannot take place until the void water has been removed. The process of becoming more dense in increasing time is known as consolidation.

Fig. 10 is a simple illustration of consolidation. The spring "A" represents soil solids. The solids are surrounded by water forming a two phase relationship. Initially the load **L** is supported partially by the water and partially by the spring. The system remains static if — and only if — the water is contained.

In the event the water is allowed to escape through valve **B** a reduction in the system volume occurs at a rate that is entirely dependent upon the rate that the water is allowed to escape. The compression of the spring is analogous to increasing the density of the soil. A point will be reached at which the load **L** will be supported by the spring compression. The system will again be at equilibrium, with the entire load **L** supported by the spring. Allowing additional water to escape will not produce an additional change in spring compression.

Consolidation is the inevitable result of a continued applied force resulting from:

1. Capillary action.
2. Soil body forces.
3. Surface loading.

Best evidence of capillary action is the vertical movement of water up a small diameter tube. The force exerted by this movement must be balanced by a compressive force on the walls of the tube. If the walls of the tube are the resilient grain structure of the soil, the walls will compress to a point where the capillary force is balanced by the resistance of the wall. If the grains are free to move under the action of the capillary force a change in soil volume will occur.

Water moves upward through the soil by means of capillaries formed by the individual grain boundaries. The movement is usually upward from the water table or free water surface toward the soil surface. The height of the capillary water column above the water table is dependent upon the grain size of the soil. In cohesionless sands the rise is only a few inches while in a cohesive clay the rise may be as great as 60 ft.

The amount or percent of consolidation that will occur is dependent upon:

1. **Soil permeability,** which governs the flow rate of the water.
2. **Thickness of overlying strata,** which governs the volume of water as well as the distance water must travel.
3. **Number of previous boundaries of stratum.** This influences distance the water must travel.
4. **The void ratio and the rate of change of the void ratio with pressure.** This influences both volume of water and the change in soil volume with loss of water.

Soil Settlement Due to Construction Operations

Sub-surface facilities such as mains and service laterals located in close proximity to other major sub-surface construction may be adversely affected by soil settlement. Open cuts in soils cause settlement of the soil immediately adjacent to the excavation. The magnitude of such settlement is dependent upon one or more of the following factors:

1. Kind, type, and structure of the parent soil.
2. Depth and width of the excavation.
3. Amount of lateral bracing used and care with which it is placed.
4. The magnitude and proximity of surface loading (surcharge).

Settlement results from the failure of the soil comprising the free standing sides of the cut. A lateral, inward deformation of the free standing sidewalls occurs due, principally, to the soils body forces. The surface soil immediately adjacent to the excavation is affected for some distance outwardly and laterally. The zone where ground lost due to settlement

Adapted from presentation by Robert H. Ormston, Cincinnati Gas & Electric Company, to A.G.A. Distribution Conference.

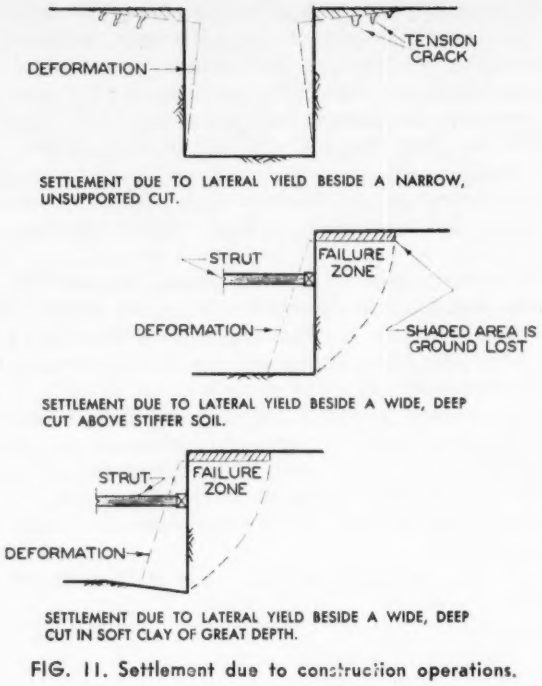

DEFORMATION
TENSION CRACK
SETTLEMENT DUE TO LATERAL YIELD BESIDE A NARROW, UNSUPPORTED CUT.
STRUT
FAILURE ZONE
DEFORMATION
SHADED AREA IS GROUND LOST
SETTLEMENT DUE TO LATERAL YIELD BESIDE A WIDE, DEEP CUT ABOVE STIFFER SOIL.
STRUT
FAILURE ZONE
DEFORMATION
SETTLEMENT DUE TO LATERAL YIELD BESIDE A WIDE, DEEP CUT IN SOFT CLAY OF GREAT DEPTH.

FIG. 11. Settlement due to construction operations.

is most probable can be related to the depth and width of the cut.

A shallow trench that is not supported laterally will, under one or more of the conditions outlined above, fail as a soil wedge tending to rotate about its bottom (Fig. 11A).

On the other hand, a relatively deep excavation that has lateral support during construction by struts, and after construction by a backfill, can not rotate about its bottom; therefore, the soil must move vertically downward, as in Fig. 11B. All movement occurs at the bottom of the cut.

Open Cuts in Cohesionless Soils

Soils of this type carry surface loading by particle to particle contact. Stability is the major concern. Stability is dependent upon the soil friction angle and amount of saturation, making it almost mandatory to install lateral bracing even for shallow cuts. Because of the ability of a cohesionless soil to carry surface loading without lateral deformation, the settlement zone is usually limited to within one-half the depth of the cut.

Open Cuts in Soft Clay

Soft clay located at the sides of a cut acts as a surcharge or surface load. Under the action of the surcharge, the clay near the bottom of the cut yields laterally toward the excavation (Fig. 11C) and the bottom of the cut rises resulting in a general settlement of the ground located above the yielding clay.

It has been found that the magnitude of the lateral movement and corresponding settlement is dependent upon:

1. Width of cut to depth of cut ratio.
2. The construction procedure employed.
3. The presence and the depth of soft clay beneath the bottom of the cut.

If a cut is very narrow — i.e., width does not exceed depth, or if the bottom of the cut is located close to the surface of firm soil — the lateral movement or yield spreads a short distance from the sides of the cut and is restricted to a relatively narrow belt located on each side of the cut.

If the cut is wide or if the clay is soft to a great depth below the bottom of the cut, the lateral yield and corresponding settlement may extend to a distance considerably greater than the depth of the cut, regardless of the care with which the sides are braced.

Excavation Tables

The various types of earth encountered during excavation work for pipe laying are usually grouped into two general classes:

1. Soft. This includes sand and loam, which may expand approximately 20 percent.
2. Hard. This includes clay, adobe, decomposed granite, and rock, which normally expand about 35 percent. Rock may expand up to 50 percent.

In Table B, spoil-pile dimensions are given for the two different classes, using an angle of repose of 33° (a ratio of height to width of 1 to 3).

Except for the amount displaced by the pipe, all excavated material — if properly wetted and tamped — will return to the trench. Volume of excavated material displaced by the pipe for all classes of soil is given in Table A.

TABLE A.
Excavated Material Displaced by Pipe

Nominal Pipe Size, Inches	Volume of excess material, cu yd per 100 ft of trench			
	Steel or Wrought Iron		Cast Iron	
	20 percent expansion	35 percent expansion	20 percent expansion	35 percent expansion
2	0.1	0.1	—	—
3	0.3	0.3	0.4	0.4
4	0.5	0.6	0.6	0.7
6	1.1	1.2	1.2	1.3
8	1.8	2.0	2.0	2.3
10	2.8	3.2	3.0	3.4
12	3.9	4.4	4.9	5.5
16	6.2	7.0	7.5	8.4
20	9.7	10.9	11.4	12.9
24	14.0	15.7	16.3	18.4
30	21.8	24.6	24.7	27.8

TABLE B.
Volume of Trench and Spoil-Pile Dimensions

(Based on 1 to 3 ratio of height to width)

Trench Depth in ft	Volume of Trench, cu yd per 100 lineal ft	Spoil-Pile Dimensions			
		20 percent expansion		35 percent expansion	
		Height (ft-in.)	Width (ft-in.)	Height (ft-in.)	Width (ft-in.)
8-in. Trench					
1½	3.7	0-11	2-8	0-11	2-10
2	4.9	1-0	3-1	1-1	3-3
2½	6.2	1-2	3-6	1-3	3-8
3	7.4	1-3	3-10	1-4	4-0
3½	8.6	1-4	4-1	1-5	4-4
12-in. Trench					
1½	5.6	1-1	3-3	1-2	3-6
2	7.4	1-3	3-10	1-4	4-0
2½	9.3	1-5	4-3	1-6	4-6
3	11.1	1-7	4-8	1-8	4-11
3½	13.0	1-8	5-0	1-9	5-4
16-in. Trench					
2½	12.3	1-8	4-11	1-9	5-2
3	14.8	1-9	5-5	1-11	5-8
3½	17.3	1-11	5-10	2-1	6-2
4	19.7	2-1	6-2	2-2	6-7
4½	22.2	2-2	6-7	2-4	7-0
5	24.6	2-4	6-9	2-5	7-4
18-in. Trench					
2½	13.9	1-9	5-2	1-10	5-6
3	16.7	1-11	5-8	2-0	6-0
3½	19.4	2-1	6-2	2-2	6-6
4	22.2	2-2	6-7	2-4	7-0
4½	25.0	2-4	7-0	2-6	7-5
5	27.8	2-5	7-4	2-7	7-10
20-in. Trench					
3	18.5	2-0	6-0	2-1	6-4
3½	21.6	2-2	6-6	2-4	6-11
4	24.7	2-4	6-11	2-5	7-4
4½	27.8	2-5	7-4	2-7	7-10
5	30.8	2-7	7-9	2-9	8-3
5½	34.0	2-9	8-2	2-11	8-7

Trench Depth in ft	Volume of Trench, cu yd per 100 lineal ft	Spoil-Pile Dimensions			
		20 percent expansion		35 percent expansion	
		Height (ft-in.)	Width (ft-in.)	Height (ft-in)	Width (ft-in.)
22-in. Trench					
3	20.4	2-1	6-4	2-3	6-8
3½	23.8	2-3	6-10	2-5	7-3
4	27.2	2-5	7-3	2-7	7-8
4½	30.6	2-7	7-9	2-9	8-2
5	34.0	2-9	8-2	2-11	8-7
5½	37.4	2-10	8-6	3-0	9-0
24-in. Trench					
4	29.6	2-6	7-7	2-8	8-1
4½	33.3	2-8	8-1	2-10	8-6
5	37.0	2-10	8-6	3-0	9-0
5½	40.7	3-0	8-11	3-2	9-5
6	44.5	3-1	9-4	3-3	9-10
30-in. Trench					
4	37.0	2-10	8-6	3-0	9-0
4½	41.7	3-0	9-0	3-2	9-7
5	46.3	3-2	9-6	3-4	10-1
5½	50.9	3-4	9-11	3-6	10-7
6	55.6	3-6	10-5	3-8	11-0
36-in. Trench					
4½	50.0	3-3	9-10	3-6	10-6
5	55.6	3-6	10-5	3-8	11-0
5½	61.1	3-8	10-11	3-10	11-7
6	66.7	3-10	11-5	4-0	12-1
6½	72.2	3-11	11-10	4-2	12-7
40-in. Trench					
4½	55.6	3-6	10-5	3-8	11-0
5	61.7	3-8	11-0	3-11	11-8
5½	67.9	3-10	11-6	4-1	12-2
6	74.1	4-0	12-0	4-3	12-9
6½	80.2	4-1	12-4	4-4	13-1

Excavation Volumes in Trenches, Etc., Cu. Yd. per 1000 Lineal Ft.

Depth of trench, in.	Width of trench, in.																					
	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
12	18.5	24.7	30.9	37.0	43.2	49.4	55.6	61.7	67.9	74.1	80.2	86.4	92.6	98.8	105.	111.	117.	123.	130.	136.	142.	148.
14	21.6	28.8	36.0	43.2	50.4	57.6	64.8	72.0	79.2	86.4	93.6	101.	108.	115.	122.	130.	137.	144.	151.	158.	166.	173.
16	24.7	32.9	41.2	49.4	57.6	65.8	74.1	82.3	90.5	98.8	107.	115.	123.	132.	140.	148.	156.	165.	173.	181.	189.	198.
18	27.8	37.0	46.3	55.6	64.8	74.1	83.3	92.6	102.	111.	120.	130.	139.	148.	157.	167.	176.	185.	194.	204.	213.	222.
20	30.9	41.1	51.4	61.7	72.0	82.3	92.6	103.	113.	123.	134.	144.	154.	165.	175.	185.	195.	206.	216.	226.	237.	247.
22	33.9	45.3	56.6	67.9	79.2	90.5	102.	113.	124.	136.	147.	158.	170.	181.	192.	204.	215.	226.	238.	249.	260.	272.
24	37.0	49.4	61.7	74.1	86.4	98.8	111.	123.	136.	148.	160.	173.	185.	198.	210.	222.	235.	247.	259.	272.	284.	296.
26	40.1	53.5	66.9	80.2	93.6	107.	120.	134.	147.	160.	174.	187.	201.	214.	227.	241.	254.	267.	281.	294.	308.	321.
28	43.2	57.6	72.0	86.4	101.	115.	130.	144.	158.	173.	187.	202.	216.	230.	245.	259.	274.	288.	302.	317.	331.	346.
30	46.3	61.7	77.2	92.6	108.	123.	139.	154.	170.	185.	201.	216.	231.	247.	262.	278.	293.	309.	324.	340.	355.	370.
32		65.8	82.3	98.8	115.	132.	148.	165.	181.	198.	214.	230.	247.	263.	280.	296.	313.	329.	346.	362.	379.	395.
34		69.9	87.4	105.	122.	140.	157.	175.	192.	210.	227.	245.	262.	280.	297.	315.	332.	350.	367.	385.	402.	420.
36		74.1	92.6	111.	130.	148.	167.	185.	204.	222.	241.	259.	278.	296.	315.	333.	352.	370.	389.	407.	426.	444.
38		78.2	97.7	117.	137.	156.	176.	195.	215.	235.	254.	274.	293.	313.	332.	352.	371.	391.	410.	430.	450.	469.
40		82.3	103.	123.	144.	165.	185.	206.	226.	247.	267.	288.	309.	329.	350.	370.	391.	412.	432.	453.	473.	494.
42			108.	130.	151.	173.	194.	216.	238.	259.	281.	302.	324.	346.	367.	389.	410.	432.	454.	475.	497.	519.
44			113.	136.	158.	181.	204.	226.	249.	272.	294.	317.	340.	362.	385.	407.	430.	453.	475.	498.	521.	543.
46			118.	142.	166.	189.	213.	237.	260.	284.	308.	331.	355.	379.	402.	426.	450.	473.	497.	521.	544.	568.
48			123.	148.	173.	198.	222.	247.	272.	296.	321.	346.	370.	395.	420.	444.	469.	494.	519.	543.	568.	593.
50			129.	154.	180.	206.	231.	257.	283.	309.	334.	360.	386.	412.	437.	463.	489.	514.	540.	566.	592.	617.
52				160.	187.	214.	241.	267.	294.	321.	348.	374.	401.	428.	455.	481.	508.	535.	562.	588.	615.	642.
54				167.	194.	222.	250.	278.	306.	333.	361.	389.	417.	444.	472.	500.	528.	556.	583.	611.	639.	667.
56				173.	202.	230.	259.	288.	317.	346.	374.	403.	432.	461.	490.	519.	547.	576.	605.	634.	663.	691.
58				179.	209.	239.	268.	298.	328.	358.	388.	418.	448.	477.	507.	537.	567.	597.	627.	656.	686.	716.
60				185.	216.	247.	278.	309.	339.	370.	401.	432.	463.	494.	525.	556.	586.	617.	648.	679.	710.	741.
62					223.	255.	287.	319.	351.	383.	415.	446.	478.	510.	542.	574.	606.	638.	670.	702.	734.	765.
64					230.	263.	296.	329.	362.	395.	428.	461.	494.	527.	560.	593.	626.	658.	691.	724.	757.	790.
66					238.	272.	306.	339.	373.	407.	441.	475.	509.	543.	577.	611.	645.	679.	713.	747.	781.	815.
68					245.	280.	315.	350.	385.	420.	455.	490.	525.	560.	595.	630.	665.	700.	735.	770.	805.	840.
70					252.	288.	324.	360.	396.	432.	468.	504.	540.	576.	612.	648.	684.	720.	756.	792.	828.	864.
72						296.	333.	370.	407.	444.	481.	519.	556.	593.	630.	667.	704.	741.	778.	815.	852.	889.
74						305.	343.	381.	419.	457.	495.	533.	571.	609.	647.	685.	723.	761.	799.	837.	876.	914.
76						313.	352.	391.	430.	469.	508.	547.	586.	626.	665.	704.	743.	782.	821.	860.	899.	938.
78						321.	361.	401.	441.	481.	522.	562.	602.	642.	682.	722.	762.	802.	843.	883.	923.	963.
80						329.	370.	411.	453.	494.	535.	576.	617.	658.	700.	741.	782.	823.	864.	905.	947.	988.
82							380.	422.	464.	506.	548.	591.	633.	675.	717.	759.	801.	844.	886.	928.	970.	1010.
84							389.	432.	475.	518.	562.	605.	648.	691.	735.	778.	821.	864.	907.	951.	994.	1040.
86							398.	442.	487.	531.	575.	619.	664.	708.	752.	796.	841.	885.	929.	973.	1020.	1060.
88							407.	453.	498.	543.	588.	634.	679.	724.	770.	815.	860.	905.	951.	996.	1040.	1090.

Earth and clay increase in bulk ¼ when dug, but subside 1/5 in height and decrease 1/6 in bulk when formed into embankments.
Sand and gravel increase in bulk 1/12 when dug; sand subsides in embankment ¼ in height; gravel from 1/10 to 1/12 according to coarseness. Rock increases ½ of its original bulk when excavated.

APPROXIMATE WEIGHT OF EARTHS, ROCKS, ETC., LB. PER CU. YD.

Sand	3000
Gravel	3000
Mud	2500
Marl	2600
Clay	3100
Chalk	3600
Sandstone	3900
Shale	4000
Quartz	4100
Granite	4200
Trap	4200
Slate	4300

QUANTITIES OF EARTH EQUAL TO A TON (as filled into trucks)

	Volume cu. ft.	Volume cu. yd.
River sand	21	0.78
Pit sand	22	0.81
Coarse gravel	23	0.85
Marl	28	1.04
Stiff clay	28	1.04
Lump chalk	29	1.07
Earth	33	1.22

NATURAL SLOPES OF EARTH

	Avg. angle with horizontal
Gravel	40°
Dry sand	38°
Sand	22°
Vegetable earth	28°
Compact earth	50°
Shingle	39°
Rubble	45°
Clay, well drained	45°
Clay, wet	16°

Contract Control of Construction

Adequate and clearly worded contracts and specifications plus conscientious and effective effort to maintain good cooperation between contractor and company can be advantageous to both parties

GAS DISTRIBUTION COMPANIES in the past few years, have shown increasing interest in levelling their gas main and service line construction work load by using contractors to do "peak shaving." The "peak shaving" of construction work load by using contractors reduces the magnitude of the work load variation of a utility's own forces.

Why use contractors for construction of gas distribution facilities?

Some companies that have peak demands for construction labor during the summer months have found it profitable to use contractors during these months rather than hire seasonal labor. Temporary labor is generally less productive and presents other problems which do not generally exist with permanent personnel. Additionally, the use of contractors makes it possible to keep overtime work at a minimum. Of course, a *special* job requiring specialized equipment, or engineering "know how" may make it necessary to use contractors at any time, since it is usually not economical to maintain special equipment and personnel for such projects.

The number of contractors' forces used range from a maximum during the heavy construction months to a minimum during the light construction period. The wide fluctuations in volume of work contracted does not seem to make the work too unattractive to the contracting companies. Of course, the contractor has some of the same problems facing him that face the utility, that is, he must find other work for those forces released by the utility during the off-peak season.

The control of contractors' activities begins in the office with the engineering, legal, and insurance groups preparing contracts and specifications that will be guide lines for the contractor and for company personnel responsible for his performance.

Contracts and specifications should be clear and concise, leaving no doubt as to intent. Simplicity can be obtained by using local contractors who have acquired local experience and developed a system of team work with the utility company.

Specifications for an "outside" contractor, especially on a complex project, must be more specific to avoid being charged for "extras" to compensate a contractor for intentional low lump sum bidding.

A second phase in controlling a contractor is in the method of bidding. Here are four of the more popular methods.

1. **Blanket or Unit Bidding.** This type is effectively used for work to be done in new housing developments or where unforeseen difficulties can be expected to be at a minimum. Competition is based on the per foot cost of pipe installed, with payment for accessory items being the same for all contractors. *The* per foot cost *includes excavation, welding of pipe, lowering in, testing, backfilling, and clean up.*

Prices for accessory work such as *resodding, repaving, bracing and shoring of trenches, abnormal rock excavation, etc.* can also be arrived at by having a number of competitive bids. With these bids plus the company's experience in such work, it is easy to arrive at prices that are acceptable to the utility and fair to the contractor.

Some observations from utility engineers concerning this type of bidding are:

"Contractor unit prices have dropped 20% in the six years of blanket bidding, which indicates increased familiarity of contractors with the work and also the effect of competition between contractors.

"It is advisable to obtain separate quotations on single and double random lengths of pipe. It is also advisable to break down the jobs into length categories such as less than 1000 ft; 1000 to 1999 ft; 2000 to 2999 ft, and over 3000 ft. With other factors being equal, the longer the job, the less the unit cost should be.

"Specifications are reprinted each year, which allows the utility an opportunity to strengthen the wording and close loopholes. They may be changed during the year by addendum but this allows the contractor to change his quotations."

2. **Lump Sum Bids.** This type of bid requires a contractor to quote a fixed amount, but specifications for the job must be prepared in such a way to preclude the need for "extra" payments for the unforeseen. Bidding of this type may be more costly, as the contractor tends to protect himself by the inclusion of a contingency to cover the unknowns he might encounter.

3. **Time and Material Bids.** For this type of bidding, a contractor should furnish rates to be charged for men, equipment, material, overheads, and profit percentage. Care must be exercised by the company to prevent the use of excessive numbers of men and equipment that would result in high total cost. This is difficult to do without leaving the company open to possible criticism by the contractor for denying him the use of adequate labor and materials to efficiently perform his work.

4. **Time and Material Bids Not to Exceed a Fixed Amount.** This type of bidding is similar to straight *Time and Material bidding* except that it provides a maximum payment. This tends to prevent the use of excessive numbers of men and equipment by the contractor and places responsibility for productivity on the contractor to a greater extent than under a straight *Time and Material Contract.*

Contract Awards

After receipt and comparison of quotations, the contract is normally awarded to the lowest bidder since it is assumed that invitations are sent only to reputable and qualified contractors. However, the job may be awarded to other than the lowest bidder if interim developments indicate the inability of the lowest bidder to complete the project on time due to other commitments.

Inspection

It is most advisable to have a distribution company engineer or field inspector, usually from the engineering or construction department, assigned to the job to assure that the contractor performs his operations in accordance with the provisions of the contract and specifications. In doing this the company inspector must scrupulously refrain from telling the contractor **how** to do his work since this tends to relieve the contractor of his responsibilities.

The following are areas in which the company inspector should have responsibility:

Adapted from presentation by B. Frank Harris, Jr., Baltimore Gas & Electric Company, before A.G.A. Distribution Conference.

1. Materials. Where materials are supplied by the utility, the company inspector should order their delivery and obtain a receipt from the contractor, who then becomes responsible for them. The company, however, should remain responsible for any defective materials and any expense involved in their replacement. Where materials are supplied by the contractor, the company has no responsibility until completion and acceptance of the work.

2, Supervision. The company inspector must be sure that the contractor provides skilled supervision during all phases of the work.

3. Alterations and Extra Work. The contractor is not allowed to make changes in the specifications or to do extra work without specific approval from the inspector. This may or may not be in writing but the latter avoids reliance on people's memory when final settlement of costs are made.

4. Permits and Regulations. The company or contractor may be required to obtain permits, licenses and easements but the inspector must see that the contractor abides by their provisions. Safety regulations should be established by the company as any accident will reflect on the company, since the public generally considers that gas main construction is being done by the local utility.

5. Inspection of Work During Construction. The company specifications should provide for a check of the welders' performance, using X-ray or radiography. Sample welds may be removed for testing and if approved, paid for by the company, while the contractor should pay for any rejected welds. The number of welds tested usually depends upon the size of the main and the type of service for which it is designed.

The contractor should be required to check pipe coating with "holiday" detectors and to repair the coating flaws at his own expense, except that the company may pay for the repair of excessive damage caused by poor mill coating or by improper handling by the company during delivery of the pipe to the contractor.

The inspector should witness the testing of the installation and specifications should require the contractor to repair any defects at his own expense.

6. Correction of Work After Final Payment. Normally, provisions are made for the contractor to remedy any defects that appear within a specified time limit. The shorter this time limit, the less the contractor will provide under contingencies to cover the work. Normally, 60 days is considered the minimum to obtain sufficient backfill compaction for the use of a Pearson-type "holiday" detector to pick up coating flaws. The contractor should be required to repair any flaws at his own expense. A longer time is desirable to check workmanship involving paving, sodding, and reseeding. A one-year limit here allows for the elements of all seasons to take effect.

There are other factors controlling construction by contractors, such as performance bonds, provisions for the contractor to indemnify the company against all damages and expense as a result of his operations, provisions for the company to take over and complete work upon default by the contractor, and the company's right to control the use of subcontractors.

This, of course, brings us back to the beginning, that proper preparation of contracts and specifications is an essential that must be carefully thought out.

With adequate and clearly worded contracts and specifications and with a conscientious and effective effort made by the company inspector to maintain good cooperation between the contractor and the company, the use of contractors to level out the utilities' construction work can and will be adequately controlled.

This should be to the advantage of both the contractor and the utility company.

Some Examples of General Contract Conditions

(These are presented for illustration purposes only. Actual contract wording depends on company requirements and legal requirements in the state and locality in which construction is to be performed.)

1. **Definitions.** Contract should define *owner* (company), *engineer* or *inspector, regulatory body, contractor, surety, contract, manufacturer,* and any other terms pertinent to the contract.

2. **Duties of company engineer or inspector** should be defined, and his authority should be outlined with regard to directing manner in which work is conducted, approval of materials, etc.

3. **Changes in work.** Company, through the engineer or inspector, may from time to time make changes in drawings and specifications and require additional work or omission of work previously ordered. Provisions of contract apply to all such changes, modifications, and additions as if they were embodied in original drawings and specifications.

4. **Status of contractor.** Contractor agrees to perform contract as an independent contractor, and not as a subcontractor or agent or employee of the company.

5. **Permits and licenses.** Company provides contractor with necessary permits for construction on or across all highways, streets, alleys, private rights-of-way, and railroads. Contractor procures and pays for all permits and licenses, and pays for all charges and fees and give all notices necessary and incident to conduct of the work.

6. **Superintendence and supervision.** Contractor provides, on job site, a competent superintendent and any necessary assistants satisfactory to the company engineer or inspector. Superintendent represents the contractor and any directions given him by the engineer or inspector in absence of contractor are binding upon the contractor.

7. **Assignment of contract.** Contractor shall not assign contract or any portion thereof to any person, persons, partnership, company, or corporation without permission of the company.

8. **Subcontracts.** If contractor has any part of the work performed by a subcontractor, provisions of contract apply to the subcontractor in all respects, as if he and his employees were employees of the contractor, and contractor is not discharged from his contract obligations but is liable for all acts and negligence and omissions of the subcontractor. No subcontracts are made without approval of the company.

9. **Owner's right to terminate contract.** Company has right to terminate contract if the contractor abandons work

to be done under the contract; if the contract is assigned; if the work is sub-let by him without permission; if the contractor is placed in bankruptcy; or if at any time the company engineer or inspector is of the opinion that the schedule of work is not being maintained or contractor is violating any of the conditions or agreements of the contract.

10. **Contractor informed as to conditions.** Contractor must state that he has examined all available records and has made field examination of the site and rights of way, informed himself of surface and subsurface conditions to be encountered, knows the location and suitability of all construction materials, local labor conditions, all requirements, regulations, and specifications of local regulatory bodies, and all other matters pertinent in connection with work and services to be performed under the contract. Contractor also must state that the contract price is based on his own knowledge and judgment of conditions and hazards involved and not upon representation of the owner or his employees.

11. **Time and order of completion.** Contractor agrees to commence and carry out work as directed by engineer or inspector in accordance with schedule of completion of work outlined in agreement.

12. **Hindrances, delays, and loss.** Contractor assumes all risks and uncertainties in connection with the work as he is compensated for them in the contract price.

13. **Quality of materials.** All materials furnished by contractor and permanently incorporated in the work shall be new and source of supply and materials themselves are to be first approved by the engineer or inspector.

14. **Protection of public, property, and persons.** Contractor must declare himself familiar with all Federal, State, and local laws and regulations framed for protection of public, his employees, and otherwise applicable to his work and takes all necessary precautions necessary to prevent accidents in any place. Contractor shall assume defense in all suits or claims brought against owner or company for and on account of any injury or damage to person or property in connection with the performance of work under the contract.

15. **Insurance policies.** Contractor is to carry, maintain, and continue in force, throughout performance of the contract, insurance in licensed companies to include: a) Workman's compensation insurance (where required); b) General public liability insurance; c) Automobile public liability and property damage insurance. Certificates of such insurance are filed with the company, and contractor or his insurer must provide prior written notice of material change in such policies or cancellation of them to the company.

16. **Protection of highways, railroads, and city streets.** Contractor shall repair and protect at his own expense public roads, city streets, bridges, to full satisfaction of city and state highway authorities.

17. **Night work.** When required to complete work or necessary in emergencies, work may be done at night, but not without knowledge and approval of company engineer or inspector.

18. **Cleaning up.** Contractor shall completely remove and dispose of all temporary works as directed and restore territory embraced within site of his operations to good order and conditions as directed.

19. **Scope of work.** Work shall consist of furnishing all labor, materials, and equipment for construction of described facilities.

20. **Materials furnished by owner.** Owner agrees to furnish materials as specified and at delivery points as shown in agreement, including all underground piping, coating materials, valves and fittings, pipe bends, boxes, concrete materials for paving repairs, etc.

21. **Materials furnished by contractor.** Contractor agrees to furnish all materials for temporary construction — for safeguarding life and property — necessary for execution of work to be performed by him. All such materials to be approved by engineer or inspector, and are to be ordered and received by the contractor.

22. **Work to be performed by owner.** As agreed upon. (Covers installation of certain facilities, if necessary, and welding, if company does own pipe welding in field.)

23. **Work to be performed by contractor.** Includes all work with exception of that to be performed by the company. Generally includes receiving, unloading, handling, and storing of pipe and other materials after delivery to contractor; all ditching and backfilling, including breaking and repairing of paved surfaces, tunneling, boring, and other excavations; hauling, string, and lining of pipe; welding of pipe; field coating of welded pipe joints; cleaning, swabbing, and inspecting of pipe to insure removal of foreign objects; lowering-in and placement of pipe; pressure testing of line; maintaining barricades and warning signals for protection of the public.

24. **Schedule of material specifications and deliveries.** Includes description of materials and delivery points for each materials item.

25. **Type of construction and other provisions.** Includes details on:

a. Receipt of materials.
b. Hauling and stringing.
c. Ditching.
d. Backfilling, replacing of paving, and clean-up.
e. Pipe cleaning and protective coating:
    1. Welded joints, etc.
    2. Inspection of protective coating.
    3. Handling of coated pipe.
f. Lining, tacking, and welding of pipe.
g. Laying and lowering-in.
h. Testing:
    1. Preliminary testing.
    2. Final testing
i. Roads and highway crossings.
j. Installation of other equipment.

26. **Contractor informed as to specifications.** Intent of specifications for all classes of work is to provide a complete installation ready for the transportation of natural gas. Contractor declares himself fully familiar with the specifications and warrants all work done by him to be completed in strict compliance with the specifications and the best construction practices. The owner, while reserving the right to inspect the work, does not obligate himself to supervise the construction to be performed by the contractor, and the contractor must assure himself that work is being properly done at all times, and is responsible for the efficiency, safety, and adequacy of his plant, appliances, and methods.

COST-IMATING

In response to many requests from readers and users of the *Gas Handbook Issue* of American Gas Journal, the 1960 issue again presents cost data designed to serve as a valuable "working tool" for engineering and operating men concerned with utility plant valuations and trends in costs of materials and equipment, as well as installed costs.

Numerous cost indexes are available for trending original cost records or for comparing — for estimating purposes — new or replacement costs of numerous items used in the gas utility industry. Cost index data presented on these two pages represents the first effort of any gas industry publication to present — as a regular service — a breakdown of many of the numerous items required to make a factual and comprehensive cost analysis.

Primarily, the cost index data presented here has been obtained from two authoritative sources — the U. S. Department of Labor's Bureau of Labor Statistics, and the *Handy-Whitman Index of Public Utility Construction Costs*. The Materials and Equipment Cost Index items are based on 1947-49 = 100, and for the Installed Costs Index the Handy-Whitman Index has been adjusted so that a 1949 = 100 base can be used to provide a measure of uniformity.

This **"Cost-imating"** feature also appears in regular issues of American Gas Journal, as new cost data becomes available. Additional items are planned for inclusion in the Materials and Equipment Cost Index as they are developed from other sources and checked for validity. *Suggestions from Handbook readers are welcomed.*

Materials and Equipment Cost Index

(Based on 1947-49 = 100, unless otherwise noted)

	1954	1955	1956	1957	1958	1959(a)	Jan. 1960	Apr. 1960	References*
Arc Welding Machines and Equipment	125.0	129.3	142.2	147.3	152.3	151.9	151.4	156.9	Code 1176
Building Materials (Non-Metallic)	120.9	124.2	129.6	134.6	136.0	137.7	138.4	138.3	Code 13-
Concrete—Ingredients	121.0	124.8	130.6	136.0	139.0	140.3	142.0	142.1	Code 132-
Concrete—Products	117.5	118.6	123.0	126.4	128.1	129.7	130.5	131.3	Code 133-
Construction Equipment (Composite)	131.6	137.1	148.6	160.0	166.1	171.9	173.6	174.7	Code 112-
Air Compressor, under 200 cfm	128.4	137.1	141.2	157.0	163.9	171.8	173.2	173.2	Code 1124-01
Air Compressor, over 200 cfm	121.7	129.2	130.3	146.0	154.6	161.1	162.4	162.4	Code 1124-02
Ditcher	124.2	129.2	142.5	152.2	142.6	147.0	150.1	150.2	Code 1123-01
Loader, Tractor, Shovel-type	125.7	127.4	136.9	149.6	155.2	161.7	162.5	162.5	Code 1122-31
Paving Breaker, Pneumatic	126.0	128.1	144.4	156.1	166.0	181.6	181.6	181.6	Code 1126-01
Power Crane, Truck Mounted	133.7	141.5	154.5	162.3	164.9	167.1	168.2	168.2	Code 1121-11
Power Crane, Tractor Mounted	111.9	115.6	120.3	129.8	135.1	135.1	135.1	135.1	Code 1121-31
Power Shovel, ½-cu yd	128.6	134.1	143.5	151.1	153.9	161.6	165.0	167.7	Code 1121-01
Tractor, Wheel-Type	123.8	126.8	130.5	135.9	137.5	143.0	143.3	144.9	Code 1128-01
Tractor, Track-Type, under 45-DHP	142.3	148.3	160.3	170.4	181.0	189.6	195.4	195.4	Code 1128-11
★Meters, Gas, Domestic	122	122	133	143	158	158	158	158	Handy-Whitman
Motor Vehicles	119.3	122.9	129.8	135.4	139.7	142.8	141.6	141.6	Code 118-
Passenger Cars	121.7	125.4	131.8	137.2	141.0	144.2	143.3	143.3	Code 1181
Trucks	113.8	118.0	127.3	134.0	139.8	142.4	139.6	139.6	Code 1182
Office Machines and Equipment	112.4	115.5	119.6	124.7	126.8	128.1	128.9	129.0	Code 1153
Pipe and Fittings									
★Cast Iron Gas Pipe	103	105	110	119	125	125	125	125	Handy-Whitman
★Cast Iron Fittings, 4 thru 24-in.	121	125	129	133	140	145	145	145	Handy-Whitman
Copper Tubing, ⅜-in.	144.6	164.3	180.6	159.1	153.6	166.9	173.0	173.0	Code 1025-53
★Steel Pipe, 2-in.	130	134	145	157	170	176	176	176	Handy-Whitman
★Steel Pipe, 16-in.	119	121	127	135	145	150	150	150	Handy-Whitman
Steel Pipe, Black, 1¼-in.	141.4	150.7	168.7	185.4	191.5	190.9	190.9	190.9	Code 1014-56
Steel Pipe, line, 8-in.	157.7	167.2	190.7	212.0	218.9	218.1	218.1	218.1	Code 1014-58
Tee, Steel, Forged, 1-in.	148.0	153.4	175.1	183.0	175.6	172.0	172.0	172.0	Code 1149-13
Pressure Tanks, Above-ground	99.9	105.5	124.8	129.6	121.1	124.9	124.9	124.3	Code 1072-01
★Regulators, Gas, House	109	109	109	109	119	119	119	119	Handy-Whitman
Tires and Tubes	130.6	144.9	152.2	150.9	152.4	144.0	133.3	138.1	Code 072
Valves									
Gate Valve, Iron, 6-in.	148.1	165.4	199.4	211.7	204.0	250.6	279.5	279.5	Code 1149-01
Gate Valve, Brass or Bronze, 1-in.	147.8	164.4	200.9	205.8	191.8	194.9	199.1	200.7	Code 1149-02
Gate Valve, Forged Steel, 2-in.	104.7	106.4	115.1	121.9	127.5	136.7	136.7	136.7	Code 1149-03
Gate Valve, Cast Steel, 6-in.	126.5	127.4	141.2	163.0	169.7	189.9	197.0	197.0	Code 1149-04

*The word "Code" refers to the revised index code number (August 1958) used in "Wholesale Prices," issued by Bureau of Labor Statistics, U. S. Department of Labor.

★Starred items have base of January 1949 = 100 and are based on data from *Handy Whitman Index of Public Utility Construction Costs*, published by Whitman, Requardt, and Associates. These items are considered to give a more reliable index of utility costs than other cost indexes as they are based on actual utility material costs and property valuations.

(a) Preliminary index number for 1959.

Gas Distribution Construction — Installed Costs Index*

(Based on January 1, 1949 = 100)

NORTH ATLANTIC REGION

(Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, West Virginia)

	Jan 1 1954	Jan 1 1955	Jan 1 1956	Jan 1 1957	Jan 1 1958	Jan 1 1959	July 1 1959	Jan 1 1960
Total Construction and Equipment, Manufactured Gas Plant	121	126	136	146	155	160	163	164
Mains, Cast Iron, Installed	115	119	128	134	140	145	150	151
Mains, Steel, Installed	128	134	146	151	161	169	176	177
Services, Installed	130	135	148	156	167	175	182	184
Meter Installation	122	130	142	153	166	173	174	179
House Regulator Installation	122	128	141	151	163	170	171	176
Gas Labor	129	133	137	142	147	151	158	167

SOUTH ATLANTIC REGION

(Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, Virginia)

	Jan 1 1954	Jan 1 1955	Jan 1 1956	Jan 1 1957	Jan 1 1958	Jan 1 1959	July 1 1959	Jan 1 1960
Total Construction and Equipment, Manufactured Gas Plant	121	125	134	146	154	159	162	163
Mains, Cast Iron, Installed	115	118	126	135	141	145	148	149
Mains, Steel, Installed	128	133	143	154	161	169	174	175
Services, Installed	121	130	142	154	162	170	175	178
Meter Installation	121	127	137	150	161	169	171	176
House Regulator Installation	121	127	136	149	160	168	170	174
Gas Labor	122	127	131	137	140	150	155	156

NORTH CENTRAL REGION

(Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin)

	Jan 1 1954	Jan 1 1955	Jan 1 1956	Jan 1 1957	Jan 1 1958	Jan 1 1959	July 1 1959	Jan 1 1960
Total Construction and Equipment, Manufactured Gas Plant	124	128	136	147	155	160	163	163
Mains, Cast Iron, Installed	120	124	129	136	143	147	151	151
Mains, Steel, Installed	135	140	148	155	165	172	178	178
Services, Installed	133	138	146	155	167	173	179	181
Meter Installation	123	130	143	155	168	175	177	183
House Regulator Installation	123	130	142	154	166	173	175	181
Gas Labor	129	134	144	146	152	160	164	167

SOUTH CENTRAL REGION

(Arkansas, Louisiana, Oklahoma, Texas)

	Jan 1 1954	Jan 1 1955	Jan 1 1956	Jan 1 1957	Jan 1 1958	Jan 1 1959	July 1 1959	Jan 1 1960
Total Construction and Equipment, Manufactured Gas Plant	120	125	133	144	152	157	159	160
Mains, Cast Iron, Installed	117	121	126	134	140	143	146	147
Mains, Steel, Installed	137	144	151	160	170	177	183	184
Services, Installed	125	131	139	150	160	166	172	174
Meter Installation	123	131	142	155	169	175	178	182
House Regulator Installation	121	128	139	156	164	170	172	177
Gas Labor	127	130	140	143	149	155	161	162

PLATEAU REGION

(Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming)

	Jan 1 1954	Jan 1 1955	Jan 1 1956	Jan 1 1957	Jan 1 1958	Jan 1 1959	July 1 1959	Jan 1 1960
Total Construction and Equipment, Manufactured Gas Plant	120	125	133	145	152	157	160	161
Mains, Cast Iron, Installed	112	116	122	131	135	138	142	143
Mains, Steel, Installed	129	135	144	153	162	170	176	176
Services, Installed	126	133	143	155	165	171	179	181
Meter Installation	123	129	140	152	167	174	177	182
House Regulator Installation	123	128	139	150	164	172	176	179
Gas Labor	134	137	143	144	153	165	172	172

PACIFIC COAST REGION

(California, Oregon, Washington)

	Jan 1 1954	Jan 1 1955	Jan 1 1956	Jan 1 1957	Jan 1 1958	Jan 1 1959	July 1 1959	Jan 1 1960
Total Construction and Equipment, Manufactured Gas Plant	121	127	137	145	153	159	163	163
Mains, Cast Iron, Installed	114	119	127	132	138	143	148	148
Mains, Steel, Installed	129	136	148	151	162	171	178	179
Services, Installed	125	133	143	150	162	171	178	181
Meter Installation	121	129	144	156	170	177	179	186
House Regulator Installation	119	128	142	154	167	173	177	183
Gas Labor	117	126	140	140	146	154	161	165

*Construction index based on *Handy-Whitman Index of Public Utility Construction Costs*, published by Whitman, Requardt, and Associates. For detailed information on costs for any year from 1912, refer to *Handy-Whitman Index Bulletin No. 72*, index at costs to July 1, 1960.

Types of Corrosion

Galvanic Corrosion

Practically all corrosion encountered in pipeline operations is galvanic in nature, wherein the chemical change is accompanied by a transfer of electrical energy. Such reactions are called *electrochemical.* In galvanic corrosion, the area from which current flows is called the **anode**; the area to which the current flows is called the **cathode**. Two types of galvanic corrosion exist — one in which dissimilar metals are in a common electrolyte, and one in which a common metal is in dissimilar electrolytes.

Dissimilar Metals. One of the most prevalent and least considered galvanic cells occurs when a piece of new pipe is placed in an old line, as in Fig. 1. The new pipe always becomes the anode and its rate of corrosion depends largely upon the type of soil and relative areas of the anode and cathode. If a very short piece of pipe is installed, the corrosion rate is usually very accelerated because the small anode area must supply current to satisfy a much larger cathode area of the old line.

Fig. 2 illustrates another common type of galvanic cell, one that is produced by differences in the surface condition of the pipe metal. Scars or scratches on the pipe surface become active anode areas soon after a line is buried. The same is true of bright surfaces of the shallow threads adjacent to a coupling or fitting. In both cases, the bright surface becomes the anode and the rest of the pipe surface is cathodic. In some soils, such corrosion cells are very active and destructive, due to the ratio of the small anodic area to a large cathodic area.

Fig. 3 shows another common type of galvanic cell occuring on the surface of new pipe. Mill scale, imbedded on the pipe surface during manufacture, acts as a dissimilar metal from the pipe wall. Current in the cell will flow from the pipe (the anode) through the soil to the mill scale and return to the pipe metal. Pits form at the anodic area.

Dissimilar Electrolytes. Galvanic corrosion of this type along pipelines is generally due to differences in soils or soil conditions. Fig. 4 illustrates a condition at a location having two completely different soil types. While the pipe is of common metal, the two different soils produce the effect of a dissimilar electrolyte, causing the pipe in the anode area to corrode while pipe in the cathodic area is protected. If the resistance to current flow through the soil from the anode to the cathode is high, the corrosion rate will be slow. Conversely, if the soil resistance is low, the corrosion rate will be rapid.

Fig. 5 shows another type of galvanic cell produced by a mixture of different soils. If large clods of dirt (usually resulting from hand digging) rest against the pipe, the area that they touch tends to become the anode of a galvanic cell. Such cells, having their anodic and cathodic areas around the circumference of the pipe, are called short path cells, and produce very rapid pitting. Machine ditching usually produces a well mixed spoil bank, resulting in a great number of small cells that tend to neutralize each other, resulting in a slow corrosion rate.

Fig. 6 shows another cell in which the soil throughout the depth of the ditch is uniform in type or kind, but the pipe rests on heavy, moist, undisturbed ground at the ditch bottom, while the pipe circumference is in contact with drier backfill. Greatest dissimilarity — and most dangerous condition — occurs along the bottom of the pipe. It can produce very severe pitting.

Stray Current Corrosion

Stray current corrosion can occur any time a pipeline is laid in the vicinity of an electrified railway, electrified manufacturing plant, or near structures that are being protected by an impressed direct current. In such cases, the ground (earth) is often used as a return path for the current. Often, however, the current strays from its direct path via some other structure — such as a pipeline. Because such currents "stray" from their desired paths, they are called "stray currents." At points where such currents flow onto the pipeline, the pipe is the cathode of a cell and is protected. Likewise, where the current leaves the pipeline, the pipe becomes the anode of the cell and will corrode.

Bacteriological Corrosion

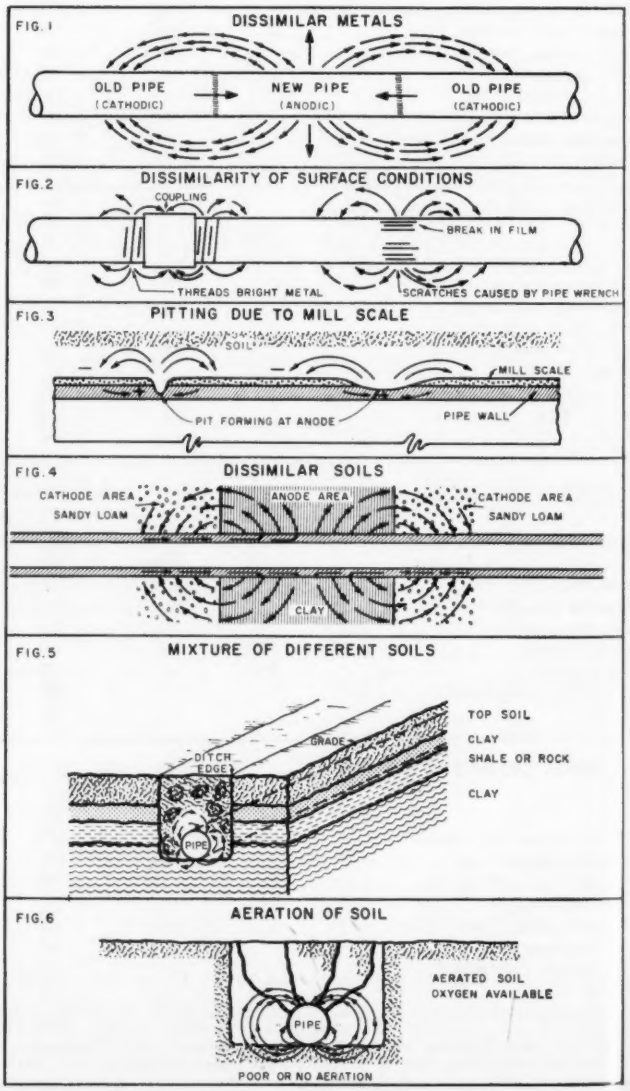
Bacterial corrosion — or more specifically, anaerobic bacterial corrosion — is often not recognized. The modern concept of such corrosion is that bacteria found in soils cause changes in the physical and chemical properties of the soils. By so doing, they produce either active galvanic cells due to differential aeration or destroy the protective hydrogen ion films that normally collect along the cathodic surface of a galvanic cell (which reduces its activity). Such corrosion takes place only under certain conditions where no free oxygen is present and results in production of sulfide as a corrosion product. It is affected by such factors as soil moisture content; whether soil is neutral or acid; abundance and type of organic matter (leaves, roots, wood type fibers), and presence of necessary chemical salts required as food for the bacteria. Additionally, the soil temperature around the pipe must be used as to permit the bacteria to grow.

Other Types

Direct Chemical Attack. While electrochemical in nature, no current flow is detectable in this type and there are no definite anodic or chemical areas. It is often the result of secondary reactions involving corrosion products or due to mechanical removal of protective films by erosion, thermal changes, or flexure of metal under load.

Dry Oxidation. This type occurs when clean surfaces of metals are exposed to air or other gases, forming oxide films and other compounds. Rate of film growth is usually greater at higher temperatures. Moisture in air or gases can accelerate rate of attack.

Atmospheric. This is a combination of electrochemical attack and direct chemical attack. It is influenced by temperature changes, alternate wetting and drying, and the washing action of elements that modify rates of film removal. A noted difference can be observed between rates of attack in industrial atmospheres and rural atmospheres.



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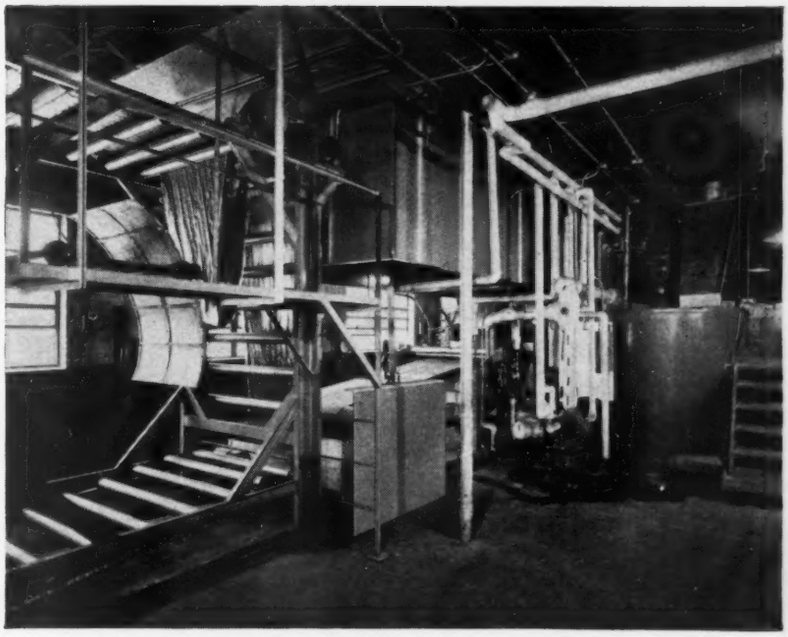

View of specially-designed machine developed after five years of research by Tapecoat engineers to convert raw materials automatically into TAPECOAT 20.

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Corrosion Data: The Electromotive Series

Electrode materials have an important bearing on the rate of corrosion, for they have a marked influence on the voltage of the corrosion cell. The various metals have been arranged by electrochemists in the order of their tendency to go into solution, i.e., to form ions. This is the well-known electromotive series, also known as the electrochemical series or the electromotive force series.

In the table, "Electrochemical Series of Metals," the voltages given are voltages obtained in a cell prepared under specific conditions in which the metal named in one electrode and a hydrogen electrode is the other electrode. Potential of the hydrogen electrode is arbitrarily taken as zero. To obtain the voltage developed when any two metals are used as electrodes, subtract the smaller electrode potential from the larger if the signs are alike, and add them if the signs are opposite.

Metals at the top of the table go into solution readily. The tendency of metals to corrode decreases as one goes down the list.

When two different metals serve as electrodes in a voltaic cell, the metal highest in the series will be anodic and will corrode; the other metal will be cathodic and usually is not harmed. The farther the metals are apart, the greater will be the voltage of the cell and the greater will be the corrosion tendency.

A metal may also displace one below it in solution. For example, a piece of iron or nickel placed in a copper sulfate solution will go into the solution in place of the copper, and copper will precipitate on the nickel or iron as a metal coating. This is called *deposition by immersion.*

Voltages given in the electrochemical series table were obtained under experimental conditions that were very definite as to the nature of the electrolyte, its concentration, and its temperature; any deviation from such conditions will give different voltages.

For example, zinc and ferrous iron show a 0.33-volt difference in the series table and the zinc is anodic. But in hot water, these potentials have been noted to reverse and the zinc becomes cathodic. The table also indicates iron is anodic with respect to cadmium but if the two are used in a solution with an iron ion concentration much greater than the cadmium ion concentration, the iron becomes cathodic.

ELECTROCHEMICAL SERIES OF METALS

(Potential is given as that between the element in its standard state and its ion at unit activity in the solution.)

Element	Reference Ion	Potential In Volts
Lithium	Li^+	—2.96
Rubidium	Rb^+	—2.93
Potassium	K^+	—2.92
Strontium	Sr^{++}	—2.92
Barium	Ba^{++}	—2.90
Calcium	Ca^{++}	—2.87
Sodium	Na^+	—2.71
Magnesium	Mg^{++}	—2.40
Aluminum	Al^{+++}	—1.70
Beryllium	Be^{++}	—1.69
Manganese	Mn^{++}	—1.10
Zinc	Zn^{++}	—0.76
Chromium	Cr^{++}	—0.71
Chromium	Cr^{+++}	—0.50
Iron (ferrous)	Fe^{++}	—0.44
Cadmium	Cd^{++}	—0.40
Indium	In^{+++}	—0.34
Thallium	Tl^+	—0.33
Cobalt	Co^{++}	—0.28
Nickel	Ni^{++}	—0.23
Tin	Sn^{++}	—0.13
Lead	Pb^{++}	—0.12
Iron (ferric)	Fe^{+++}	—0.04
Hydrogen	H^+	0.00
Antimony	Sb^{+++}	+0.10
Bismuth	Bi^{+++}	+0.23
Arsenic	As^{+++}	+0.30
Copper (cupric)	Cu^{++}	+0.34
Copper (cuprous)	Cu^+	+0.47
Iodine	I^-	+0.53
Tellurium	Te^{++++}	+0.56
Silver	Ag^+	+0.80
Mercury	Hg^{++}	+0.80
Palladium	Pd^{++}	+0.82
Platinum	Pt^{++++}	+0.86
Bromine	Br^-	+1.06
Gold (auric)	Au^{+++}	+1.36
Gold (aurous)	Au^+	+1.68

Changes taking place in a solution as corrosion proceeds may bring about a shift in relative potentials in the two electrodes.

Actual voltage of an electrode will vary with the type of electrode, alloying metals in the electrode, type of solution, and the concentration and temperature of the solution.

The electromotive (or electrochemical) series table should be used cautiously. Electrode potentials obtained in practice are not always the same as standard potentials and erroneous conclusions can be drawn and costly mistakes made by rigid applications of the standard electrode potentials when conditions are other than standard.

For a given corrosive medium, it is possible to establish a series, called a "galvanic series," in which various metals are ranked according to their potentials in that medium.

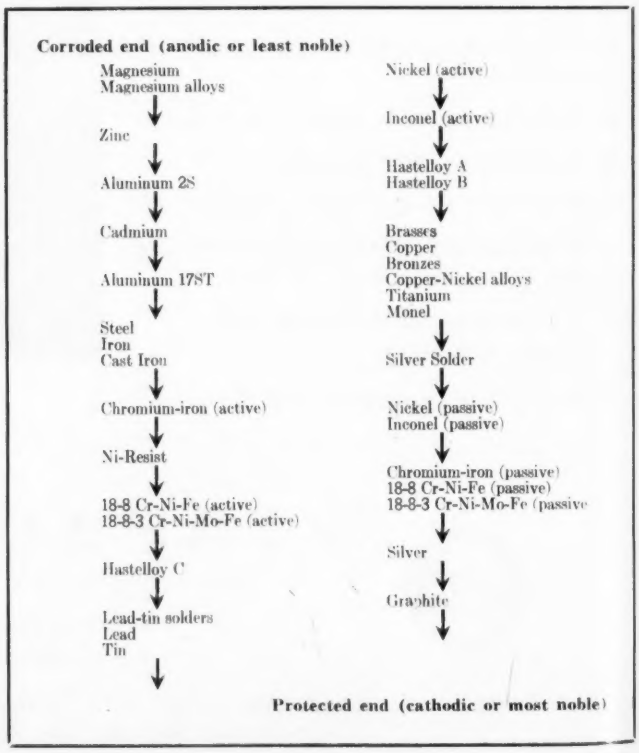
One reason for not stringently applying the standard electrode potentials is that the potential difference between two metals is merely an indication of an initial tendency toward corrosion. The actual rate of corrosion is determined by 1) the magnitude of the current flowing, and 2) the electrochemical equivalent of the anodic metal. The current is determined by the potential difference **and** the total resistance of the circuit.

Severity of the corrosion depends upon total current flow and the area in which anodic current is concentrated. Steel and iron, for example, are anodic to copper and brass. A brass valve in an iron pipe will not greatly damage the pipe, due to the relatively large area of the anode. An iron valve in a copper line, however, would be destroyed rapidly, especially in a sufficiently conductive electrolyte.

The value of the electromotive (electrochemical) series table is that it can serve as a guide to corrosion engineers who understand the full significance of the table, and they can use this knowledge in designing and planning installations in which corrosion is kept to a minimum.

Galvanic Series of Metals and Alloys

Metals grouped together have no strong tendency to produce galvanic corrosion on each other and are relatively safe to use in contact with each other. Coupling of two metals from different groups and far apart from each other in the series will result in accelerated, or galvanic, corrosion of the higher metal in the list. The greater the distance between the two metals in the list, the greater will be the tendency to corrode. Because every corrosive condition is different, it is not practical to tabulate voltage values for combinations of metals. Galvanic effect is actually determined by quantity of current generated (measured in amperes or milliamperes) rather than potential difference measured in volts or millivolts.



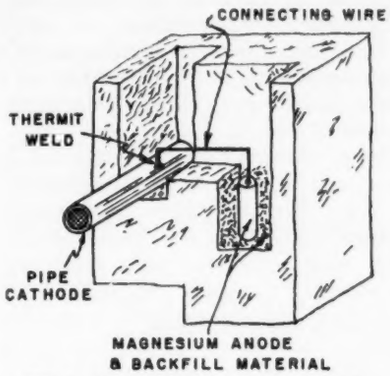


FIG. 1. Cathodic protection with single anode installation.

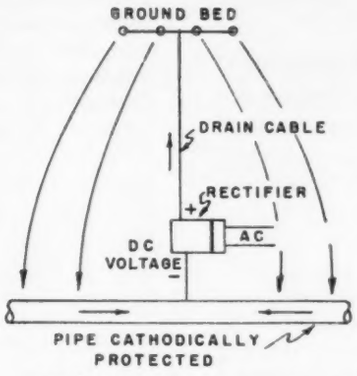


FIG. 2. Cathodic protection with single rectifier and ground bed (anode).

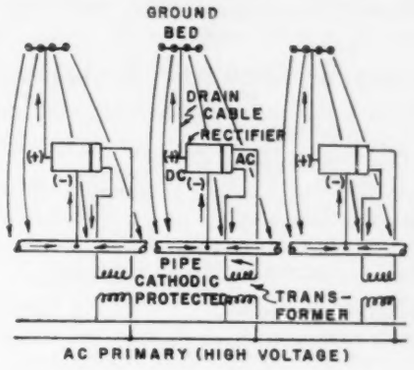


FIG. 3. Cathodic protection with distributed rectifiers with single ground beds.

Corrosion Control Methods

THE most common means of corrosion protection are coatings, extra pipe wall thickness, cathodic protection, and a combination of any two or all of these methods.

When a new line is laid today, all of these methods of corrosion protection are available and a choice of methods of corrosion control is usually based on economic factors.

The use of extra pipe wall thickness is rapidly decreasing because other means of corrosion control are now generally more economical. This is easily understood considering that the cost of pipe is based primarily upon its weight. Wall thickness is now usually determined by the design pressure of the line and little, if any, wall thickness is added to compensate for corrosive action of the soil.

There are many pipe coatings available today, and all are manufactured in accordance with high standards. These coatings* are actually used to insulate the pipe from the soil. It is practically impossible to lay a pipe line so that no holidays exist in the coating after the line is backfilled. A holiday-free coating can be obtained by using certain types of detectors to go over the backfilled line, locating all holidays, then digging the line up to patch the coating. After this has been done, perhaps several times, it is possible that a line could be checked and found to be free of holidays. Such rigid coating requirements are uneconomical. Seasonal changes in the condition of the soils cause high stresses to be exerted upon coatings, which in time distort and weaken them materially.

Thus, a coating with absolutely no holidays immediately after construction, may in time contain a large number of holidays. If pipe passes through corrosive soil, leaks will probably occur in these holidays within a very short time because the corrosive action is concentrated in very small areas.

A satisfactory, economical and most effective method of corrosion protection is to properly apply a good coating with suitable reinforcing wrappers, and then apply cathodic protection. Good quality coating, properly applied and carefully handled during installation and backfill, will keep to a minimum the number of holidays existing on the completed line. Total current requirements on such lines for cathodic protection are almost negligible. Cathodic protection costs are usually proportional to current requirements and the cost of applying cathodic protection to a well coated line is small, often less than two percent of the cost of the coating. Applying cathodic protection to these lines gives the equivalent of a practically perfect coating — if the cathodic protection is properly installed and maintained so that it operates continuously.

*The following section of this handbook — on pipe coatings — discusses them in detail.

Corrosion control on older lines, laid years ago when construction practices had not been developed, presents an entirely different problem. The following methods should be considered:

a. Repair leaks until pipe becomes unsafe to operate, then replace
b. Immediate replacement
c. Reconditioning
d. Cathodic protection

Methods (a) and (d) are most generally used. Replacement is expensive and is usually delayed as long as possible, provided the pipe is safe to operate. Reconditioning is usually as expensive as replacement.

In some cases, the most economical means of corrosion control is simply to keep leaks repaired until the pipe becomes unsafe to operate, then replace the unsafe sections. This is often true of small lines operating at low pressures. Once replacement is made, however, the problem of protecting the replaced sections becomes that of protecting new pipe, and selection of a corrosion control method should be made on that basis.

The use of cathodic protection has increased enormously during the past 10 to 15 years. Its effectiveness has been well demonstrated over long periods by many applications. Savings effected by its application include:

a. Reduction of public hazards incident to free gas
b. Reduction of utility insurance premium for public liability and property damage protection
c. Cost of pipe leak location work and subsequent pipe repair
d. Damages
e. Loss of good will
f. Loss of revenue

Chief advantages of cathodic protection are the reduction of gas leakage and the public hazard incident thereto, and the prolongation of the service life of the pipe.

Pipe coating is one of the most effective components of corrosion control. It should be selected on a basis of proven quality and performance. The most important requirements for a good underground pipe coating are low moisture absorption (less than ½ of 1 percent) and good resistance to hydrocarbons and soil stresses. Pipe coating should be disturbed as little as possible when repairing pipe. When damage to the coating cannot be avoided, it should be carefully replaced with the same type of coating or one having a similar composition.

To be effective, cathodic protection must be applied continuously. Experience has shown that cathodic protection

units must be kept in operation at least 90 percent of the time, and the closer this figure approaches 100 percent, the more effective will be the results.

Types of Cathodic Protection Equipment

Several types of cathodic protection installations are currently in use.

The common types are:

a. Galvanic anodes (Magnesium or zinc bars)
b. Rectifier units
   1. Isolated rectifier units
   2. Distributed rectifier system.

Galvanic Anodes

A magnesium (or zinc) bar buried with a special backfill in a hole near the line, with a small copper wire connecting the bar to the pipe, is the simplest type of cathodic protection installation. It is called a galvanic anode because the current comes from a "galvanic" or chemical reaction between the magnesium and the soil, just as current from a dry battery is generated by reaction of the zinc can with the chemical in the battery.

In a dry battery no current flows until a circuit is provided by connecting a wire or other conductor between the carbon pole and the zinc pole. Similarly, no current flows from the magnesium bar until a return path is provided by connecting the wire from the pipe to the bar. When so connected, current flows from the bar into the soil, is picked up on the pipe, and returns through the metal pipe and the connecting wire to the anode. Cathodic protection is received on the pipe where current is picked up from the soil. Several bars are generally installed in a group to produce more current than could be obtained from a single bar. By varying the spacing between the bars, the amount of current obtained can be controlled. It is important, when installing galvanic anodes, that they be properly spaced.

Rectifier Units

Rectifier type installations consist of equipment for converting power purchased from a commercial power company (usually 115-v a-c) into low voltage direct current required for cathodic protection. The positive (+) terminal of the rectifier is connected to a ground bed and the negative (−) terminal to the pipe. When the rectifier is turned on, it forces current through the ground bed into the earth, where it spreads out and is picked up on the pipe and is returned to the rectifier through the negative connection.

Selecting Proper Equipment

When the corrosion situation on a system is such that cathodic protection is needed, several factors must be considered. One of these is suitability of the equipment relative to operating field conditions. Proximity and location of foreign-owned underground metal structures with respect to the line to be protected are also very important. Unless an operator gives careful and cautious consideration to this factor, he may create adverse corrosion conditions for the foreign pipeline operator. He has a moral as well as a legal responsibility to plan and install his pipe protection in such a manner that it will not be detrimental to foreign structures due to the effects of "stray" protection current. Thus, selection of location for the installation of pipe protection facilities may be as important as the selection of proper equipment.

What is the best kind of equipment for cathodic protection? Any equipment or type of cathodic protection installation will be as effective as any other type if it delivers sufficient current, is continuous in operation, and applies the current to the pipe where it is needed. There may be a considerable difference in cost, however.

One ampere, applied to a pipeline, provides the same amount of protection regardless of where the current comes from. It makes no difference how many volts are required to push the current through the circuit. For example, a rectifier with a poor ground bed might be set at 4-v to push one ampere through the ground bed, into the earth and to the pipe. With a good bed, only ½-v at the rectifier might push one ampere through the circuit. The line receives the same protection in either case, although power costs would be higher in the first case.

An important step in selecting cathodic protection equipment at a new location is to estimate as accurately as possible how much current will be required to protect the section under consideration. Often it is necessary to rely on past experience, using records of units previously installed, to make an estimate of current requirements.

Three factors influence how much current a pipeline will require for protection:

a. Type and condition of pipe coating
b. Area of pipe
c. Environment.

Bare pipe can be completely protected but a heavy current is required (30 to 80 amp per mile of pipe depending on diameter and environment). A well coated, new line usually takes only a fraction of an ampere per mile, even with large diameter pipe. Over a period of time, as the coating deteriorates, more current is required for protection. Even a poor coating, by present day standards, has been found to reduce current requirements considerably.

The second factor is fairly obvious. The larger the pipe diameter, or the longer the section to be protected, the higher the current requirement will be.

The third factor, environment, probably affects current requirements less than the first two factors, but soil type, drainage, type of backfill, proximity to other metallic structures, and other environment factors must be considered.

Equipment for Protecting New Pipe

New pipe with a good coating presents no appreciable problem from a cathodic protection standpoint. A relatively small current will protect several miles and a good coating causes the current to spread out effectively, so that the current source can be located almost anywhere along the line with equal results. Galvanic anodes weighing about 17 lb per bar generally produce about 0.1-amp each and last about 10 years with practically no maintenance. They cost from $12 to $25 each installed, depending on local conditions. New pipe can thus be protected for an estimated 10 years with a total outlay of some $50 to $150 per mile. Whether magnesium or zinc is selected depends on local conditions. Zinc is very effective in low resistant soils. Being lower in the electrochemical series than magnesium it has a lower driving potential, an advantage when the pipe to be protected has a low initial pipe-to-soil potential, since it automatically prevents excess current being expended to build up pipe-to-soil potentials in excess of requirements. On the other hand, this low driving potential is a disadvantage in high resistant soil, as it limits the output obtainable. The high driving potential of magnesium makes it very desirable for use in high resistant soils and applications where initial pipe-to-soil potentials are high.

If commercial power is available at some convenient point, a single small rectifier might be installed instead of galvanic anodes. More flexible output adjustment is obtainable with the rectifier, and if soil resistance is high, the necessary higher driving potential can be easily obtained. Initial cost of a small rectifier installation should be between $200 and $500 with an annual operating cost of $100 to $200. It can be expected to protect 10 miles or more new pipe, depending on quality of coating and environment.

Protecting Bare or Poorly Coated Pipe

Large diameter bare or poorly coated pipe may require 30 to 80 amp per mile for protection. Current does not spread out readily on such a line and less total current will

be required if current is applied at many points along the line as can be done with a distributed rectifier system or with galvanic anodes well distributed along the line. If the average current requirement for such a pipeline were 60 amp per mile, approximately 600 galvanic anodes would be required per mile. At $12 to $25 each, initial cost is relatively expensive even if the full 10 years life can be realized from the anodes.

Hot Spot Protection

Bare pipe will always corrode much more rapidly in certain sections than in others. Since it is rarely economical to place a bare line under complete cathodic protection, it becomes necessary to locate the "hot spots" in order to place the protection where it will do the most good. This protection, when properly applied to the "hot spot" areas, may be expected to prevent up to 90% of the leaks, at a cost of approximately 15% of that of complete protection.

Hot spots can be located by two methods. The first (and most reliable) is a soil resistivity survey. Most convenient method for making a survey of this type is by means of a single rod apparatus, which consists of a steel rod with a metal tip insulated from the rod proper, and a small battery powered alternating current bridge, using a pair of headphones to indicate balance. This apparatus is sometimes referred to as a "Sheppard's Cane."

When making the survey, readings should be taken near pipe depth and at intervals ranging from as little as 10 ft to as great as 200 ft. It is important to catch any significant changes. Visual inspection of the terrain usually will help to make sure that none are missed.

The values of soil resistivity obtained can be plotted on semilogarithmic paper as a resistivity profile of the line. The reason for using semilog paper is because percentage comparisons are the important consideration. Sudden dips in the resistivity profile indicate areas that require further investigation and probable protection.

Values of resistivity are an indication of the corrosivity of the soil. The following rules may be used for guidance:

1. **Values below 1000 ohm/cm.** are almost always corrosive except when they are relatively short sections lying between areas of still lower value, or when they comprise the highest values in a long section of line.

2. **Values above 10,000 ohm/cm.** are almost never corrosive; sometimes a short section of such soil will be somewhat corrosive when sections on either side have much higher values. Local cell action may also be a problem in these areas.

3. **Values between 1000 and 10,000 ohm/cm.** must be interpreted by comparison with immediately adjacent sections. The low areas will be the corrosive sections.

Pipe-to-Soil Potential Method

The second method of locating "hot spots" is by means of a pipe-to-soil potential survey. Due to the fact that corrosion takes place when electrical currents leave the pipe at the anodic areas and return to it at cathodic areas, it is possible to detect these areas by means of a change in the potential drop through the soil. It is convenient to refer all soil potentials to that of the pipe itself because even quite large currents can produce relatively small potential differences in the metal compared to that through the soil.

Readings are taken using a potentiometer voltmeter combination, along with a copper-copper sulfate half cell as reference electrode. Readings are taken at the surface of the ground and directly above the pipe for the basic plot of the pipe to soil potential profile. In locating the anodic and cathodic sections, it may be of value to remember that — at the anode — the highest reading is directly over the pipe with lower readings on either side. At the cathode, the reverse is true, but the change in readings is not as great.

This type of survey is easier to make and can be made rapidly. If a trouble spot is located, it can be defined by a few additional readings. A distance of 100 ft between readings on coated lines and 50 ft on bare lines seems to be a good spacing for the initial survey work.

When the "hot spots" have been located along a bare line, current drainage of 2 milliamps per sq ft of pipe area to be protected should be provided. The amount of pipe of various sizes that can be protected by various size anodes is as follows:

Nominal Pipe Size (in.)	Spacing in feet for anode weights			
	9 lb	17 lb	32 lb	50 lb
4	22	41	78	121
6	15	28	53	82
8	11	21	40	63
10	9	17	32	50
12	8	14	27	43

These figures are based on 50% anode efficiency, 2 ma. per sq ft, and a 10-year anode life. If the conditions are such that the current output is higher than the 10-year rating, the anodes will protect a longer section of pipe for a shorter period of time and if the current output is less the anode lasts longer but protects a shorter section of pipe.

The normal 10-year-life ratings and the soil resistivities in which they are expected are:

Anode Size	Current for 10-Year Life (ma.)	Soil Resistivity (ohm/cm.)
9	51	3200
17	97	1900
32	183	1050
50	285	720

The tables above apply to one set of conditions, which are a 50% anode efficiency, isolated anodes, and 10-ft separation between pipe and anode. Higher efficiencies (which are commonly realized) will result in longer anode life. Grouping of anodes rather than single installations tends to restrict current flow. Placing anodes closer to the pipe increases current flow. However, most of the increased current will flow to the pipe in the immediate vicinity of the anode and as a result sections between anodes may not receive adequate protection.

General Procedure for Locating Hot Spots

1. **Determine importance of facility to overall company operations.**
2. **Study line history** (leak reports, sections replaced, bellhole inspection reports).
3. **Complete corrosion survey:**
   a. Soil resistivity test on right-of-way.
   b. A pH measurement of water and stream crossings, swamps, and marshes.
   c. Pipe-to-soil potential survey. (Frequency of the soil resistance tests and P/S readings should range from 10 ft to 400 ft depending upon accuracy desired.)
   d. Side drain measurements at predetermined intervals or at high potential areas.
   e. Test hole inspection of hot spots.
4. **Correlation of information:**
   a. Line history
   b. Bellhole examination of pipe
   c. Thickness of pipe
   d. Pressure involved

General Procedure for Hot Spot Protection

1. Apply magnesium anodes or magnesium ribbon
2. Apply impressed current via rectifier and ground beds
3. Electrolysis drain (stray currents)
4. Apply coatings
5. Bond to foreign lines.

Guide To Protective Coatings For Pipe

The cost of pipe protection represents a sizable figure in the total installation cost of pipe. Value of the protective coating as a barrier between the metal and the environment is only equal to the materials used, the method of application, and the final inspection of the finished job.

Because of the value of the coating it would be expected that the company installing the line would use every precaution to see that the line is installed properly. This, however, is not the case. Many installations are completed without any or with very poor inspection with the result that the line would probably have lasted longer if it had been installed bare.

Some of the poor jobs can be traced to the lack of knowledge of the proper type of coating to be used, poor control of coating temperature, poor pipe cleaning operation, applying the coating over dead primer, improper application of tape or wrong tension, careless handling of the coated pipe after being coated or during lowering in and backfilling operation.

In recent years, manufacturers of coating materials have so improved their products that coatings can, in effect, be tailor-made for specific applications.

Coatings for underground applications may be divided into several general classifications:

1. **Bituminous**
   a. Coal tar (distilled from coal).
   b. Coal tar plus epoxy resin.
   c. Asphalt (distilled from oil).
   d. Asphalt (from natural asphalt beds).
2. **Waxes and greases**
   a. Heavy consistency grease (distilled from oil).
   b. Wax (distilled from oils).
3. **Plastic tapes**
   a. Polyethylene—normal density.
   b. Polyethylene — high density.
   c. Polyvinyl chloride.
   d. Polyesters.
4. **Extruded plastic coatings**
   (Mill applied, extruded onto pipe)
5. **Epoxy resins.**
   (Powder form, spray-applied to preheated pipe).

Testing of Coatings

So that coatings from different manufacturers having similar characteristics may be held within certain limits a series of tests have been developed. A brief resume of the various terms and what they mean will be given.

Melting Point. When heat is applied to pitches and asphalts and enamels made from them, the material does not pass suddenly from a solid state to a liquid state. A gradual softening of the pitches takes place as the temperature is increased becoming fluid only after passing through several stages of gradually increasing softness. The melting or softening point in both coal tar and petroleum industries is used as a gage of the consistency or hardness of the pitches and certain compositions made from them. The following is of importance in securing a coating for desired results.

1. High melting point bases and low filler content offer maximum resistance to soil stress or pressure deformation.
2. Low melting point bases and high filter content are less resistant to slide or sag.
3. Generally, bases having a high filler content are of lower melting point and are not highly resistant to soil stress or pressure deformation.
4. In a given melting point range the compounds having a lower filler content can be applied at lower temperatures and are not subject to large evaporation loss. In contrast the higher filler content compounds may suffer a greater loss by evaporation.

Flowability. This can be stated as the application temperature required to secure a good flow and a given thickness of coating.

In field application the temperature of the agitated enamel is watched carefully and the thickness of the applied coating checked with a pit depth gage to make sure that a coating thickness of 2/32-in. or 3/32-in. is secured. The atmospheric temperature will control to a great extent the application temperature of the enamel. This condition will affect practically all enamels and can only be checked by the pit depth gage where the temperature varies during the application period.

Evaporation Loss. Most enamels contain volatile liquids that will evaporate from the enamels if the heat is held to a high level for a considerable period of time. If the coating is held at a temperature above that recommended by the manufacturer the flexibility will be lost and the enamel will become brittle. It must be under continuous agitation to prevent coke formation. If this should occur the entire batch is generally discarded.

Soil Stress. When pipe is installed in the earth and covered with backfill it is subject to mechanical forces generated by its contact with the bottom of the ditch and by expansion and contraction of the soil as it passes through wet and dry stages. The metal is of sufficient strength to resist such mechanical stresses under ordinary conditions. The materials used to protect the pipe from corrosion do not have this strength so the soil will act upon them. To prevent excessive damage a wrapper is applied over the enamel and bonded to the enamel. In so doing it is often possible to eliminate the damage caused by soil stress. The addition of the wrapper also reduces damage caused by abrasion and reduces the penetration of small stones that are in the bottom of the ditch.

Water Absorption. It is generally conceded that corrosion of underground pipe would not exist if moisture is prevented from contacting the metal. If the coating waterproofs the pipe it also prevents contact of the metal with its environment which may contain acids, alkali and other contaminants that adversely affect metal.

Ash and Filler Content. The mineral content of most pipe line enamels results from the intentional addition of minerals of various kinds during the manufacturing process. *The ash or filler content of itself is of little significance until correlated with other data.*

Slide or Sagging Tendencies. In construction work it is sometimes necessary to allow the coated pipe to remain on top of the ground for a period of time before installation. During this time the pipe is exposed to the heat of the sun and to atmospheric temperatures that may approximate the melting or softening point of the tar. When such a condition exists the coating will tend to slide or sag, reducing the thickness of the coating on the top of the pipe to such an extent that its value as a protective coating is greatly depreciated. In selecting an enamel this condition must be taken into consideration.

Primers

Primer will not stick to a dirty, wet or rusty surface and for this reason it is necessary that the pipe be clean before the primer is applied. In some instances the cleaning may be accomplished by the use of cutters and wire brushes. In others where the pipe has a heavier rust film it may be necessary to sand or grit blast the metal surface before the primer is applied.

A good bond cannot be secured if the coating is applied over a primer that has been applied over mill oil or lacquer, it has been found that a good bond is not secured. In fact, during warm weather it is sometimes possible to roll the coating off the pipe when it has been applied over the mill oil.

Primers will gradually lose their volatile liquids after they have been applied to a metal surface for a period of time because of evaporation. The primer is said to be dead when this occurs and if enamel is applied over a dead primer it will not bond. The period of time after application before the primer becomes dead depends upon the heat and humidity of the air. The best test for a dead primer is to see if it will flake off

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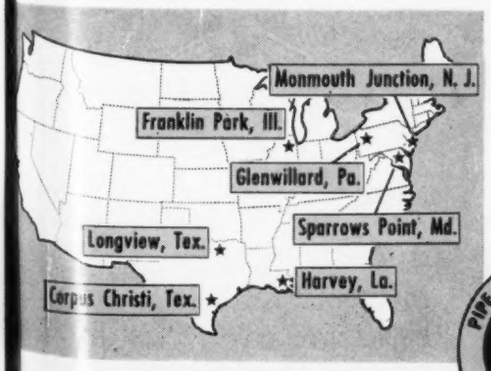

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when the fingernail is scraped over it. When this occurs the cleaning machine is run over the pipe and it is again primed.

Coating Procedures

Manuals published by the coating manufacturers explain the general procedure when the pipe is coated either in the mill or over the ditch. The following conditions have been noted during actual procedure and are not in the manuals.

A considerable number of faults are picked up by the jeep as soon as the coating machine kicks off. These may be relatively close together for a hundred feet or more. Look for:

Dust. Dust on the primer will cause jeeps.

Moisture. Most, if not all, primers contain a small amount of moisture. When the percentage exceeds 1 to 2 per cent it will cause a considerable number of jeeps. This condition will continue as long as the primer is used. The faults look like craters with the bare metal exposed at the bottom. The pits are most frequent on the top and side of the pipe close to the top where the enamel is at its highest temperature. The remedy is to secure new primer.

Coke. When a coating machine is made ready for use it is customary to heat all the parts with a high temperature torch. During this operation the material from the last operation may change to coke. This will flow with the coating when the machine is put into operation. Particles of coke will cause the coating to jeep. If it does not clear in a short time check the kettles to make sure the coating has not formed into coke. Never depend upon the thermometers in the coating kettle. Check with a portable thermometer.

Mechanical Faults. When the coating machine is put into operation some parts of it may rub the pipe causing the enamel to be either too thin or be removed. This can be checked by watching the machine. In flood coating types the iron is often found to rub. This is apparent when the faults occur on either up or down grades.

Solvent Faults. As the coating runs to the coating machine from the kettles it is giving off fumes. This is some of the volatile liquids evaporating because of the heat. This solvent will gather on the frame of the coating machine and drop off on the coated pipe. When the jeep passes over these spots they will show a fault in the coating. The remedy for this condition is to keep the machine clean.

Faults Covered by Wrappers

Asbestos felts as used for pipe line wrappers will absorb a certain amount of moisture. If the moisture content becomes too high it will cause a steam to form when hot enamel comes into contact with it. When the steam is trapped under the wrapper it will cause a blister which will blow the enamel from the pipe surface. At times this can be observed by wisps of steam given off at the wrapper surface. The remedy for this is preventive. Keep the felt in a good storage room with a good roof and keep the felt from contacting the dirt or cement floor. If it becomes too bad the felt will have to be discarded.

If the material used to saturate the felt contains too much naphthalene, the naphthalene will tend to form on the surface of the felt in the form of white crystals. The naphthalene crystals will evaporate when the heated enamels contact them and form a gas that may affect the enamel in a manner similar to steam. It may also cause a sufficient loss of solvents to cause the saturating material to become brittle causing the felt to break readily when being used.

Mill Coated Pipe

When hot enamels or waxes are applied at a coating mill the conditions under which they are applied are much more favorable than over the ditch or yard applications. Moisture and dust on the pipe to be coated is seldom if ever encountered. Asbestos felt wrappers used over the coatings are stored under conditions that preclude an excess of moisture being absorbed. Even though these conditions do not exist, faults in the coating will occur making it necessary for the applicators to test the coated pipe with high voltage electricity to expose the faults. Because a paper is used as a packaging material for the pipe it is customary to use a higher test voltage than would be used for an over the ditch coating. This is because the dielectric of the paper is added to that of the enamel and the felt.

Most difficulties encountered with mill coated pipe occur during the unloading, stringing and bending operations. Protection of the pipe at the welds often presents a considerable problem. Hot enamel, rubber tapes, and plastic tapes are used for joint protection.

Grease Coatings

Chief constituent of a grease type coating material is petrolatum obtained from the residue of the distillation of paraffin base crude oils. The consistency of the grease is controlled by the distillation process or by the addition of mineral fillers.

Some greases can be applied as a cold coating during warm weather but must be heated when weather becomes cold. Grease coatings are sometimes applied over rusty metal but if a good coating application is desired the pipe should be cleaned of all dirt and rust.

Grease coatings should never be installed in a dry soil unless a wrapper is applied to prevent the soil from contacting the grease. Where this is not done the grease becomes diffused into the soil by osmosis with the result that no coating remains on the pipe. In some soils or waters there may be a tendency of the material to saponify. The electrical resistance of a grease type coating is low even if a wrapper is used.

Wax Coatings

Base materials for wax type coatings are obtained from the distillation of paraffin base crude oils. The melting point is in the same range as asphalts and coal tar pitches.

Waxes are applied to the pipe at the coating mill and over the ditch by the travel liners. Wrappers are used in conjunction with this coating. They include plastic tapes and a form of tobacco cloth with an acetate backing. Asbestos felts are also used, in which case they are not saturated with either asphalt or coal tar cut backs. The wrappers are bonded to the wax during the application procedure and the entire coating is tested with high voltage electricity in a manner similar to that used for hot applied asphalts or tars. The potentials used are of the same value as used with other types of coatings.

Plastic Tapes

Plastic tapes have only recently come into wide use as protective coatings for underground and overhead piping although they have been used for a considerable period of time in the electrical industry. Base materials for the plastics used in the tape are natural products processed through chemical plants. The virgin plastics materials are calendared into a film and during the process a pressure sensitive adhesive is applied to one side of the film.

All plastic tapes for wrapping underground pipe fall into two general categories. In the first, the backing is classified as a primary functional protective wrap and the adhesive selected serves merely as a means of applying this functional wrap to the pipe. The second approach is to use the adhesive mass as a primary protective coating and to consider the backing merely as a carrier or protective shield.

Various thicknesses of backing and adhesive and selection of their composition all relate in either case to the approach used. There can be combinations of two approaches.

Film Thicknesses. PVC (polyvinyl chloride) tapes are normally supplied in two thicknesses. The 10-mil tape includes an 8-mil PVC film plus adhesive thickness of 2 mils. The 20-mil tape includes a 16-mil thickness PVC film plus a 4-mil adhesive thickness. Poly-

ethylene tapes are supplied in several thicknesses—a 12-mil tape (adhesive thickness of 4 mils plus an 8-mil film), a 14-mil tape (4-mil adhesive plus 10-mil film), and two types of 20-mil tape (one has 4-mil adhesive plus 16-mil film, the other has 5-mil adhesive plus 15-mil film).

Additional thickness of the adhesive film is important and desirable where the surface to which the tape is being applied is rough. The extra thickness permits the adhesive to extend to the bottom of the rough area, thus securing stronger bond.

When a plastic tape with a pressure sensitive adhesive is applied to pipe, the metal surface should be free of rust, dirt, dust, and mill scale. For this reason, it is good practice to apply a primer to the metal surface just prior to tape application.

For protection against abrasion, an additional wrapper can be applied over the plastic tape. Tar or asphalt saturated asbestos felt wrappers may be used for this purpose. They are not bonded to the tape and act only as an abrasion resistant wrapper.

Coal Tar Tapes

Coal tar tapes have been used for protective coatings for over 20 years. Developed initially for protectively wrapping and coating welded field joints, they have found many other applications.

Both hot-applied and cold-applied tapes are available. Hot-applied tapes require use of a torch to heat the underside of the coating immediately prior to wrapping. Cold-applied tapes are wrapped directly over primed surfaces.

The coal tar tapes generally consist of a layer specified thickness of coal tar pitch applied to a coal tar saturated fabric, plus a somewhat thinner coal tar coating on top, with a separator (paper or plastic film) on top of the outer layer. Newer types of coal tar tapes include refinements in the coating for a wider range of applications and use of a special plastic film that serves as both separator and outer wrap for protection against abrasion.

Extruded Plastic Coatings

One of the newest applications of plastics materials to pipe protection is the extruded polyethylene coating, applied at the mill to small diameter pipe. The coatings are a special high molecular weight polyethylene extruded over a rubber-based adhesive compound that holds the coating to the pipe. The coating is cut back at the ends to permit welding and joints are wrapped with pressure sensitive tapes.

Epoxy Coatings

A new coating recently introduced is an epoxy resin with a complex catalyst and pigment that is supplied as a single component in powdered form. This coating is applied to preheated pipe. Catalytic or hardening action is speeded by the heat and the coating is said to become hard in less than a minute. Best results are obtained by mill or coating yard application.

Another new coating, known as butoxy resin, is currently undergoing tests. The coating is applied as a liquid to the pipe by spraying. A ring burner following the spray heads maintains a temperature of about 500 F on the coated pipe surface for a few seconds to speed curing of the coating.

A combination coal tar pitch-epoxy resin coating has been available for several years. The coating, a combination of coal tar pitch with an epoxy resin and catalyst, provides a hard coating with excellent adhesion that retains good working flexibility. No wrappers are needed with this coating. The two component system is best applied at the mill, using heated pipe for fast curing.

Reinforcing Materials

In this classification fall the various materials used to reinforce hot applied coatings by becoming an integral part of the coating or a wrapper that is bonded to the enamel so that a greater resistance to sag and penetration is secured. In the latter case they also act as a shield against backfill.

Asbestos Wrappers

The general term for wrappers of this type is asbestos felt. They are composed of a mixture of asbestos and rag combined together with a binder and saturated with either an asphalt or tar cutback. The rag content of the felt wrapper will vary between 10 to 25% while the asbestos will be either long or short fiber type. There is a tendency for this wrapper to pick up moisture if not stored under proper conditions.

The wrapper is applied directly over the hot enamel as it is flooded or sprayed on the pipe. In this manner it becomes tightly bonded to the enamel. Tension of the wrapper should be so adjusted that it does not pull through the hot enamel and come in contact with the metal surface. This can be accurately checked by cutting out a section of the coating at the lap in the wrapper and making a physical examination. It is often indicated by the size at the bead formed at the lap in the wrapper. If the bead is of considerable size, the felt has been pulled in too tight squeezing the enamel out at the lap. Excessive tearing of the felt during the application will indicate too much tension or it may be caused by evaporation of the volatile liquids out of the cutback used to saturate the felt.

Ordinarily a 15-lb felt wrapper is used as an outerwrap with hot enamels. In the last few years a wrapper having a weight of only eight pounds has been developed. To keep this wrapper from tearing excessively it has been reinforced by the use of glass threads running parallel with the wrapper.

Care should be used to secure the right wrapper for the enamel that is to be applied. Thus, if a coal tar enamel is to be used the wrapper should be saturated with a coal tar cutback and when an asphalt enamel is to be used a wrapper saturated with an asphalt cutback should be used.

Glass Outer Wrap

Glass outer wrap is a thick film of glass fibers saturated with a composition of tar and asphalt cutback. It is applied in the same manner as asbestos felt over the hot enamel coating.

Paper Outerwrap

When pipe is coated at a coating mill a paper outerwrap is applied over the felt wrapper to protect it during shipment and handling. On some over-the-ditch jobs it has also been used. In this case it is probably used to resist the damage caused by backfill. Paper has a relatively short life when it is installed underground because of rot and bacteria action. Paper should not be applied over and bonded to the enamel.

Glass Inner Wrap

Glass in the form of single filaments laid down in a random form and bonded together with some type of bonding material is formed into a wrapper that is used with hot enamel applications. Sufficient tension is applied to this wrapper to pull it into the enamel but not through the enamel to the metal surface. This is said to add strength to the enamel and reduce the tendency to sag and offer more resistance to penetration. Care should be exercised to make sure that the glass filaments are completely saturated with hot enamel. Unless this is accomplished it is possible for capillary action to draw water into the enamel where the glass is exposed.

Rockshield

This material is made from scraps from the manufacture of asbestos roofing etc., and is formed into sheets of different lengths, widths and thickness and is used as an additional shield around the coated pipe where a considerable amount of rocks are encountered in the backfill or where the pipe will be handled roughly because of the terrain. Because of its thickness it cannot be wrapped around the pipe but is installed in the form of sheets that are fastened around the pipe with steel strappings or by use of glass filament tape with an adhesive. * * *

Estimating Data For Requirements for Wrapping Pipe with Kraft Paper, Felt, or Glass Fiber

Pipe size, in.				In squares		In 400 ft rolls		In 800 ft rolls		In 1000 ft rolls		In 1200 ft rolls	
Nominal	Outside diameter in.	Lap, in.	Width, in.	Per mile	Per 1000 ft	Per mile	Per 1000 ft	Per mile	Per 1000 ft	Per mile	Per 1000 ft	Per mile	Per 1000 ft
2	2.375	½	4	41.6	7.9	31.2	5.9	15.6	3.0	12.5	2.4	10.4	2.0
2½	2.875	½	4	49.5	9.4	37.1	7.0	18.6	3.5	14.8	2.8	12.24	2.3
3	3.5	½	4	59.4	11.3	44.5	8.4	22.3	4.2	17.8	3.4	14.8	2.8
3½	4.	½	4	67.3	12.8	50.5	9.6	25.3	4.8	20.2	3.8	16.8	3.2
4	4.5	½	4	75.2	14.2	56.3	10.7	28.2	5.4	22.5	4.3	18.8	3.6
4b	5.	½	4	83.2	15.8	62.5	11.8	31.3	5.9	25.0	4.7	20.8	3.9
4b	5.	½	6	80.0	15.2	40.0	7.6	20.0	3.8	16.0	3.0	13.3	2.5
6	6.625	½	6	105.0	19.9	52.5	10.0	26.3	5.0	21.0	4.0	17.5	3.3
8	8.625	½	9	132.0	25.0	44.0	8.3	22.0	4.2	17.6	3.3	14.7	2.8
8	8.625	¾	9	135.3	25.6	45.2	8.6	22.6	4.3	18.1	3.4	15.1	2.9
10	10.75	½	9	164.0	31.0	54.7	10.4	27.4	5.2	21.9	4.2	18.2	3.5
10	10.75	¾	9	167.5	31.7	55.8	10.6	27.9	5.3	22.3	4.2	18.6	3.5
11	11.75	½	9	179.0	33.9	59.7	11.3	29.9	5.7	23.9	4.5	19.9	3.8
11	11.75	¾	9	183.0	34.7	61.0	11.6	30.5	5.8	24.4	4.6	20.3	3.9
12	12.75	½	12	190.9	36.2	47.7	9.0	23.9	4.5	19.1	3.6	15.9	3.0
12	12.75	¾	12	194.6	36.9	48.7	9.2	24.4	4.6	19.5	3.7	16.2	3.1
—	14.	½	12	209.2	39.6	52.3	9.9	26.2	5.0	21.0	4.0	17.4	3.3
—	14.	¾	12	213.4	40.4	53.4	10.1	26.7	5.1	21.4	4.1	17.8	3.4
—	16.	¾	12	243.3	46.1	60.9	11.5	30.5	5.8	24.3	4.6	20.3	3.8
—	16.	1	12	247.8	46.9	62.0	11.8	31.0	5.9	24.8	4.7	20.7	3.9
—	18.	¾	12	272.0	51.5	68.0	12.9	34.0	6.5	27.2	5.2	22.7	4.3
—	18.	1	12	278.3	52.7	69.6	13.2	34.8	6.6	27.8	5.3	23.2	4.4
—	20.	1	18	301.0	57.0	50.2	9.5	25.1	4.8	20.1	3.8	16.7	3.2

Estimating Data For Approximate Quantities Required To Coat Pipe with Primer and Enamel

Nominal pipe diameter	Primers		Enamels			
			Single coat and wrap		Double coat and wrap	
	Gal per 1000 ft	Gal per mile	Lb per 1000 ft	Tons per mile	Lb per 1000 ft	Tons per mile
2	1½	8	540	1.5	—	—
2½	1½	8	680	1.8	—	—
3	2	10	800	2.1	1150	3
3½	2	10	930	2.5	1300	3.4
4	2	10	1200	3.2	1700	4.5
6	3	18	1770	4.6	2500	6.5
8	5	24	2300	6 0	3200	8.4
10	6	30	2850	7.5	4000	10.5
12	7	35	3400	9.	4800	12.5
14	7.5	39	3700	9.8	5200	13.7
16	8	44	4300	11.4	6000	15.8
18	10	50	4800	12.7	6700	17.6
20	11	55	5400	14	7500	20

Above figures are for new pipe. For old, rough pipe, add approximately 20 percent, depending on condition of pipe. Approximately 5 percent should be added for waste if pipe is rotated and 10 to 15 percent for sling application.

Protecting Gas Services Against Corrosion

Most gas distribution companies today use steel pipe for gas service lines and such lines, properly protected, will have long life. While cathodic protection is one of the first considerations given to service line design, it is usually the last part of the installation.

To properly protect steel services, several basic considerations must be undertaken:

1. Service should be isolated electrically from other unprotected structures — such as unprotected mains, house piping in contact with water piping or any electrical grounding system, and structural metal framework.
2. Pipe must be adequately coated.
3. Local dissimilar metal cells should be eliminated.
4. Cathodic protection — using sacrifical anodes or rectifiers—should be used to supplement the coating.

Cathodic protection, it should be noted, is the "insurance policy" that provides the final measure of protection. Rectifiers, because of size, cost, and operating complexities, are not often used to protect service lines. Instead, sacrificial anodes are most commonly used to provide the necessary protection. The accompanying table outlines various requirements of cathodic protection systems for services using magnesium anodes.

Procedures for applying protection depends to a large degree on the type of main to which the service line is connected. Points that should be carefully checked are outlined in the following paragraphs.

Bare Steel Mains. Services connected to bare steel mains should be isolated from both the main and the house piping. Steel fittings should be used for connecting the service to the main. Any convenient place on the service line can be used as the insulating point. Anodes should be sized to adequately protect the line.

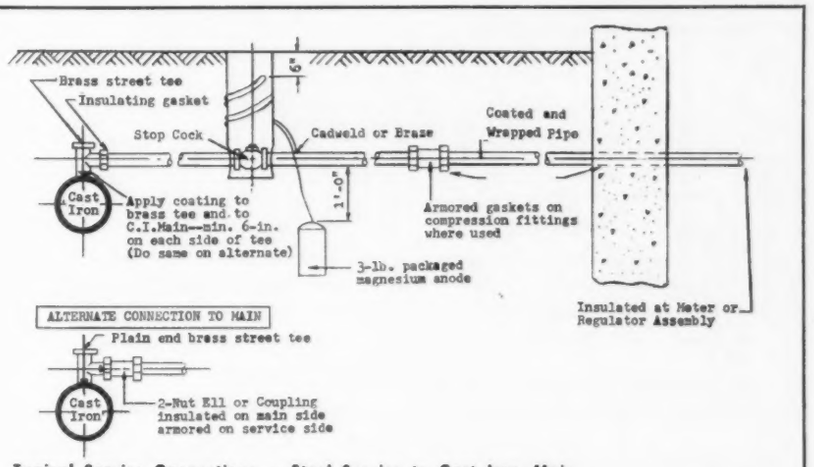
Coated Steel Mains. Services connected to coated steel mains are isolated at the connection to the main only if the service is to be given separate protection. Such isolation is advantageous in that it appreciably reduces the possibility of shorts between the main and nearby structures. It is disadvantageous in that it requires installation of individual anodes on each service line.

More common practice is joint protection of mains and services, which permits use of rectifiers instead of anodes, or the use of much larger anodes — which are more efficient, have higher output, and can be replaced much more easily than would be possible by using many smaller anodes.

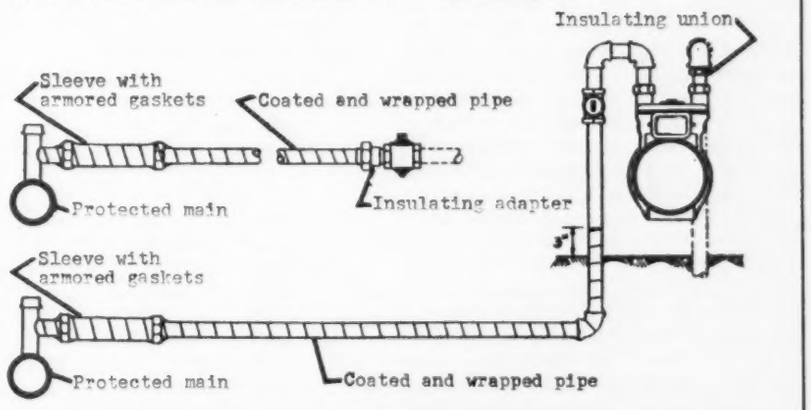
Cast Iron Mains. Services connected to cast iron mains should be isolated at the outlet side of the street tee, and isolated at the point of connection to the meter or meter-regulator set. The steel service should be electrically continuous between points of isolation, by using compression fittings with armored gaskets or bond wires, or by using welded joints. Protection is completed by adding a packaged anode of proper size.

Main Connections. Even though one of the basic objectives of a planned corrosion prevention program is to eliminate dissimilar metal cells, this idea is subject to deviation by use of the brass tee for connecting services to cast iron main. This is a compromise measure. Brass is chosen over wrought or malleable iron because it is cathodic to the cast iron, and although the cast iron main is subjected to galvanic action, such action is negligible because the anode to cathode area ratio is heavily in favor of the anodic cast iron. Cell action is also reduced by coating the brass tee and the main for at least 6-in. on each side of the main. In all cases, the brass-to-steel connection should be insulated.

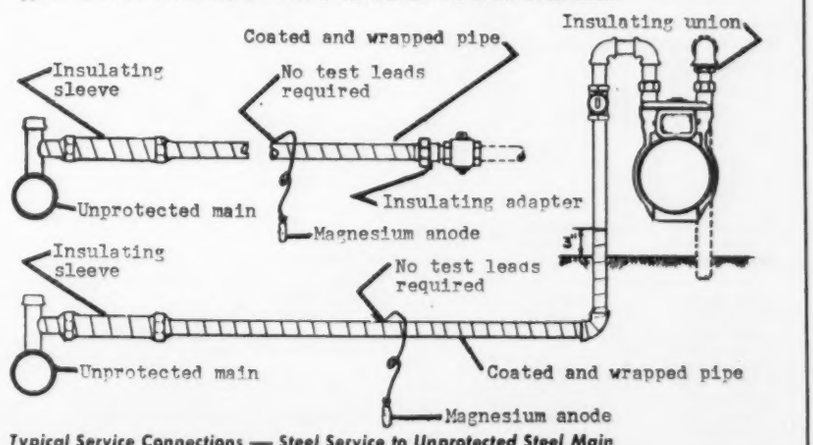
Insulation. At each residence, a water line and a gas line are attached to the water heater. To separate the water system from the gas system, an insulator must be inserted into the gas line. Where gas is metered on the outside of the house, insulating meter swivels or insulating unions are very effective.


Brass street tee
Insulating gasket
Stop Cock
Cadweld or Braze
Coated and Wrapped Pipe
Cast Iron
Apply coating to brass tee and to C.I.Main--min. 6-in. on each side of tee (Do same on alternate)
1'-0"
Armored gaskets on compression fittings where used
3-lb. packaged magnesium anode
Insulated at Meter or Regulator Assembly
ALTERNATE CONNECTION TO MAIN
Plain end brass street tee
Cast Iron
2-Nut Ell or Coupling insulated on main side armored on service side

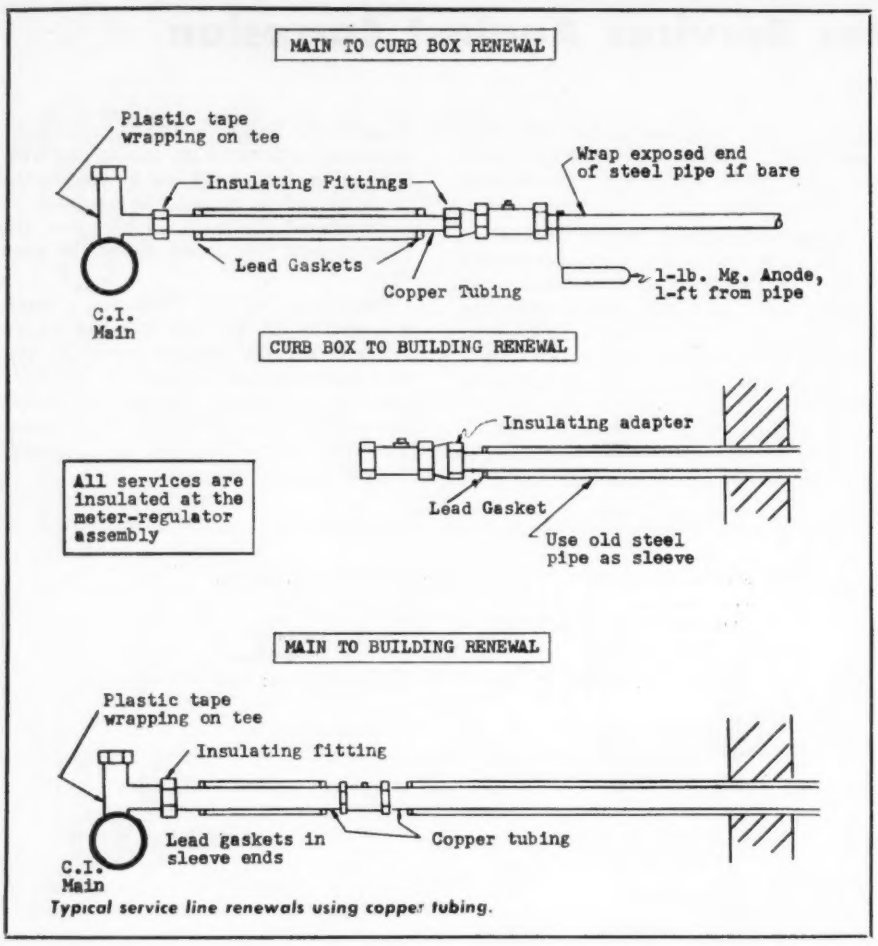
Typical Service Connections — Steel Service to Cast Iron Main



Typical Service Connections — Steel Service to Protected Steel Main



Typical Service Connections — Steel Service to Unprotected Steel Main



Typical service line renewals using copper tubing.

In areas where meters are installed inside homes, usually in basements, the problem is more complex. Homeowners inadvertently find many ways to render an insulating swivel useless; all sorts of metallic objects can be found attached to or stored on the gas and water lines to effectively join them from a conductance standpoint. An effective way to counteract this is to insulate in the risers on the outside of the house using an insulating union as shown in the accompanying illustration.

It is also much easier to check service line insulators when they are installed in this manner. Unfortunately, insulating devices many times are damaged upon installation because of excessive tightening. They can then become conductors. Finding them can be very tedious work, as one shorted insulator will affect cathodic protection on several blocks of the gas distribution system.

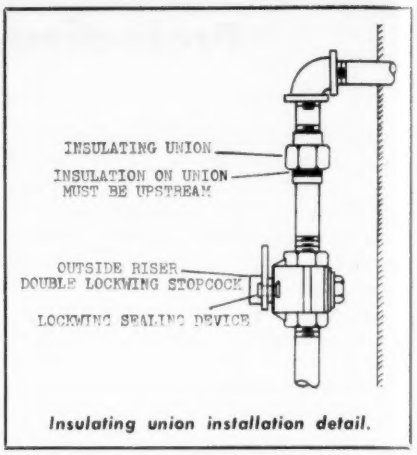
Points to Check to Insure Protection. Here are some items that should be checked to make sure that the installed line is properly protected:

1. Be sure that insulating fittings at meter-regulator end of service are not shorting.
2. Check house piping to make sure that it does not touch any service piping ahead of the meter. Make sure householder does not lay metal objects across the service line.
3. Make sure that all connections are either definitely insulating or definitely electrically continuous. Test all insulating fittings before backfilling. Use armored gaskets or bond wires across compression fittings, and make sure pipe is clean for good contact.
4. Use native backfill around anodes.
5. Make sure curb boxes do not touch curb cock or main — or, if they must touch, make sure they are insulated from each other.
6. Check cathodically protected services periodically by taking a pipe-to-soil potential reading.

CATHODIC PROTECTION CHART

Magnesium Anode System

Type of Main to which service is connected	Insulating fitting at main?	Insulating fitting at meter set?	Size of Anode Required	Remarks
Bare Steel	Yes	Yes	3 or 5-lb	
Coated Steel (unprotected)	Yes	Yes	3 or 5-lb	Use if service to be protected separately
Coated Steel (unprotected)	No	Yes	9 to 32-lb	Use if service and main are to be protected together
Coated Steel (protected)	Yes	Yes	3 or 5-lb	If separate protection desired
Coated Steel (protected)	No	Yes	none	Joint protection
Cast Iron	Yes	Yes	3 or 5-lb	


INSULATING UNION
INSULATION ON UNION MUST BE UPSTREAM
OUTSIDE RISER DOUBLE LOCKWING STOPCOCK
LOCKWING SEALING DEVICE

Insulating union installation detail.

Service Line Renewals

In an effort to reduce costs incurred in digging up old services and replacing them with new lines, many companies have turned to renewing leaking steel services by using inserts of copper tubing or plastic tubing.

Higher cost of the copper or plastic tubing is offset by reduced expense of digging trenches and replacing lawns. The method is applicable throughout the year and is not affected by having to dig through frozen soil, as experienced by many gas distribution companies in the northern states.

Plastic Insert Renewals. Non-metallic and inert by nature, plastic services and plastic tubing inserted into old steel services require no protection. About the only requirement is that the old steel service—if used as a sleeve—be isolated from the main and from the meter set. This is usually done by cutting away a section of the older steel pipe at each end.

Copper Renewals. Copper services are more corrosion resistant than steel, and because of their slower corrosion rate, the application of protection is not critical.

Unintentional protection is given copper services, however, by the steel or cast iron pipe to which they are connected. If a service is only partially renewed with copper, the remaining steel service line will not have a long life, as the copper-to-steel cell that is established will hasten the corrosion process — which, presumably, made necessary the partial renewal.

For proper protection, all copper used in service renewals should be insulated from both the steel or cast iron main and from the remaining sections of the steel service. Lead gaskets or bushings have proven useful in this respect, being used to seal the ends of the old steel service, which is used as a sleeve. The sleeve, in turn, becomes anodic for any copper exposed to the soil.

As shown in the accompanying illustration, when a partial renewal is made with copper tubing, it is usually necessary to protect the remaining steel section with a sacrificial anode, properly sized. ★ ★ ★

Gas Service Design

For Residential and Small Commercial Services

Pressure Ranges

Although gas is distributed at many different pressure ranges, most companies consider as low pressure any pressure less than ½ psig. In this report, intermediate pressure is taken as from 1 to 15 psig and high pressure from 15 to 60 psig. A maximum pressure of less than 50 psig is preferred by most companies while the maximum pressure allowed within the house is limited to 25 psig by more than 50% of the companies.

Pipe Sizing

Most important problem initially in the design of a gas service is selection of the pipe size. Many different bases are available and used in selecting the proper size. Some use a maximum size for all services; others make a detailed pressure drop calculation for each installation. Here is a brief description of the methods followed by a majority of the companies:

Consideration of connected load, length of service, and main pressure are made in selecting service pipe size. Generally this combination of variables is handled by means of selecting an allowable pressure drop for a particular main pressure and then selecting the pipe size based upon length of service and anticipated load, which will result in a calculated pressure drop of less than the allowable.

As it is usually the easiest to determine the connected load on a gas service, this flow is used to size the service pipe. Some companies refine the principle by introducing a diversity factor based upon the assumption that all of the appliances will not be in use at the same time. Others assume that the service will ultimately supply a piece of gas space heating equipment and size the service for this load even if no house heating load is installed at present.

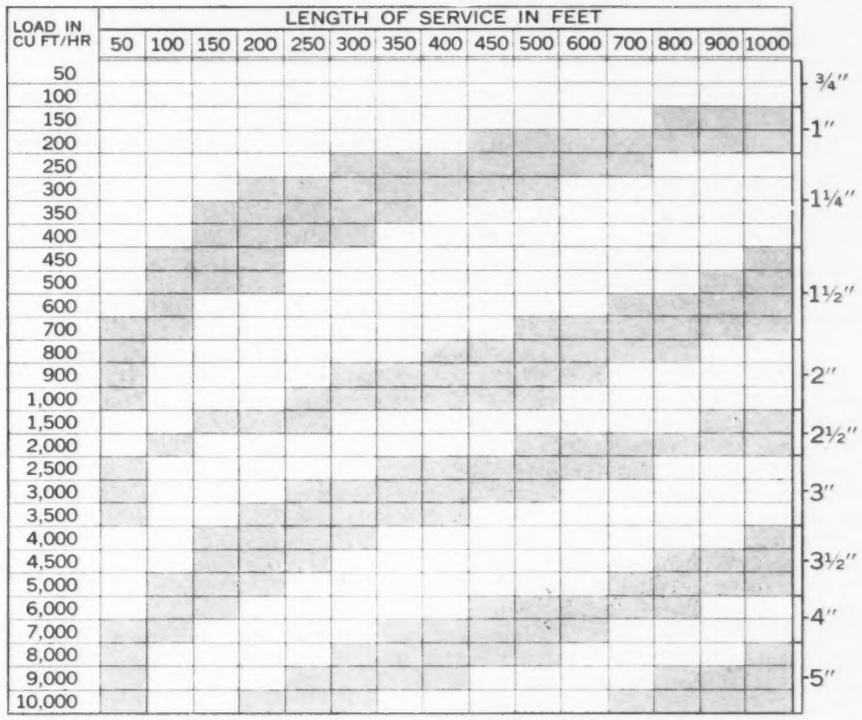
The pressure drop allowed on a gas service is primarily a function of the pressure being carried on the mains during the time the mains are supplying the peak demand.

In a low pressure system, operating at a nominal main pressure of from 6 to 8 in. of water column, most companies consider the maximum allowable pressure drop on a gas service to be either 0.3-in. or 0.5-in. of water column.

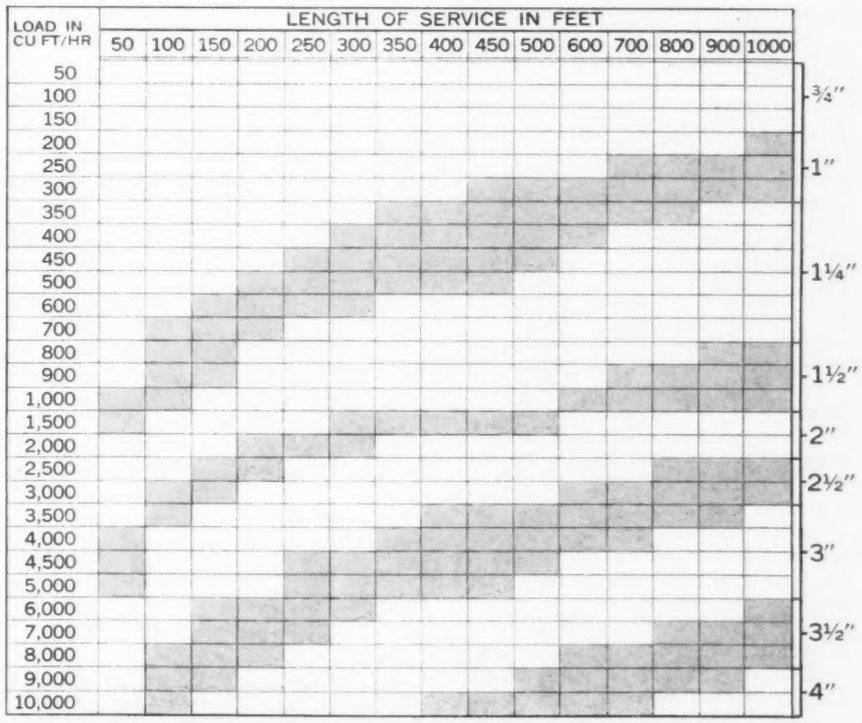
An intermediate pressure system operating at a main pressure of from 1 to 15 psig will generally permit an allowable pressure drop of about ½ psig.

High pressure distribution systems permit allowable pressure drops of from ½ to 3 psig. Another method of selecting the allowable pressure drop is to specify that it be some percentage of the main pressure during the maximum hour. This varies from 10 to 20%.

These various methods are basically to be used in sizing services that will supply large loads. Construction practices, avail-



Service Sizing Chart, low pressure.



Service Sizing Chart, intermediate pressure.

FLOW CAPACITY – CFH – SP. G. 0.70						
LENGTH IN FEET	STANDARD STRAIGHT STEEL PIPE					
	0.3" H_2O DROP		7.0" H_2O DROP		1/2 lb. DROP	
	1"	1 1/4"	1"	1 1/4"	3/4"	1"
10	270	490	1270	2390	880	1900
20	240	440	1130	2100	790	1650
30	210	385	1010	1850	700	1420
40	180	332	885	1600	610	1225
50	162	295	785	1440	540	1100
60		270	710	1300	490	1010
70		250	660	1200	460	935
80		234	615	1130	430	880
90		220	580	1070	405	825
100		210	555	1000	385	780
120		190	505	925	348	710
140			470	860	322	660
160			440	800	300	615
180			415	750	285	580
200			390	715	270	550
250			350	639	240	493
300			320	580	220	448

Steel pipe capacity.

FLOW CAPACITY – CFH – TYPE "L" COPPER TUBING – SP.G. 0.70												
LENGTH IN FEET	0.3" H_2O DROP		0.5" H_2O DROP		7.0" H_2O DROP			1/2 lb. DROP			1 lb. DROP	
	1"	1 1/4"	1"	1 1/4"	3/4"	1"	1 1/4"	3/4"	1"	1 1/4"	1/2"	3/4"
10	290	530	384	685	730	1400	2550	1025	1980	3600	380	1460
20	250	455	332	590	630	1210	2200	900	1750	3100	325	1250
30	220	395	287	520	550	1070	1900	770	1500	2700	285	1100
40	190	345	252	450	475	930	1650	675	1310	2325	248	950
50	170	308	223	400	450	830	1480	600	1160	2080	220	865
60		280	205	367	395	760	1350	545	1060	1900	200	780
70		260	190	340	360	700	1250	510	980	1750	185	725
80		244	178	319	340	660	1160	475	925	1640	173	675
90		230		298	320	620	1100	447	870	1550		640
100		219		282	300	590	1050	422	815	1475		610

Copper tubing capacity.

ability of materials, and reduced inventory lead many companies to specify certain pipe sizes for services. In low pressure systems 1¼-in. pipe is generally preferred by most, although 1½-in. pipe is specified by about one-third.

In intermediate and high pressure systems the favorite minimum pipe size is ¾-in. with some 1-in. pipe specified for use in intermediate pressure systems. These "standard" sizes have been selected by the companies using them because they will provide adequate capacity to meet the more detailed requirements outlined in the preceding paragraphs.

Construction Specifications

Having selected a pipe size, the next problem is to design the construction specifications so that the service, when finally built, will conform to the established practice of the industry, comply with the applicable rules and regulations under which the company operates, and will be the safest and most economical service possible.

Several state regulatory commissions have enacted codes that govern in broad principles the design and construction of gas services. The gas industry, itself recognizing the need for a code or method of the practice common to all parts of the country, has cooperated and assisted in the revision and expansion of Section 8 of the American Standards Associations Code for Pressure Piping.

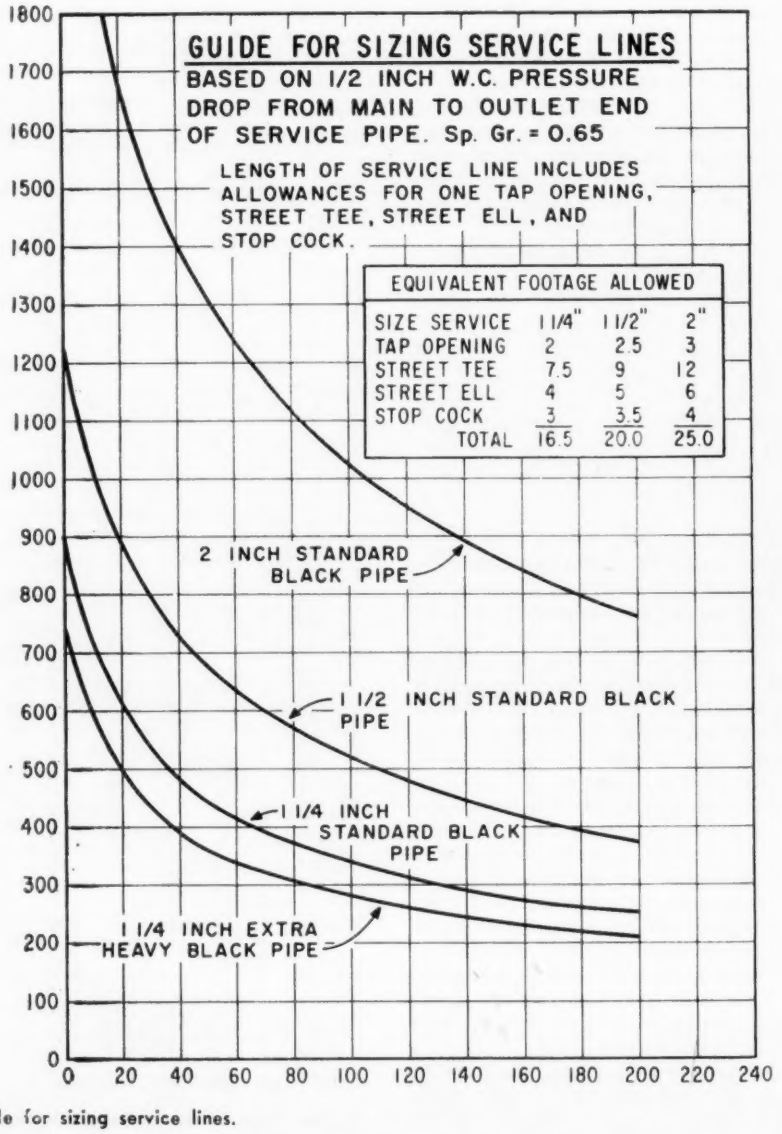
Here are some sample requirements extracted from various state codes:

Curb cocks must be installed on all services where a regulator is installed on customer's premises, and on all low pressure services where large groups of people gather. These curb cocks must be inspected annually. *(New York Code).*

House regulators and vents must be inspected and tested periodically to see that they are operating properly and vented safely. *(New York).*

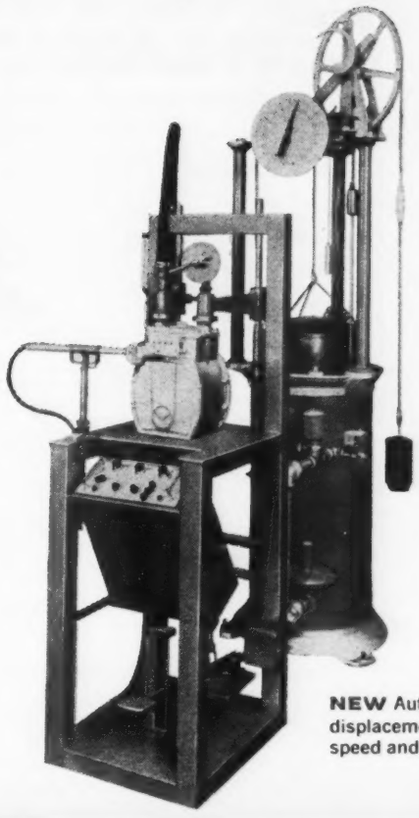
Tamper-proof service cocks are to be installed on all services requiring a house regulator and should be inspected periodically. *(New York).*

House regulators operating at pressures greater than 10 psig shall be equipped



Guide for sizing service lines.

American Meter offers the only complete line of Precision Measurement Equipment



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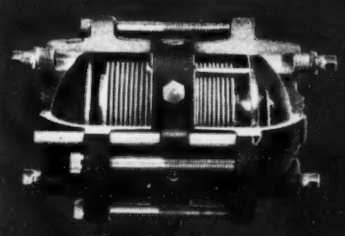

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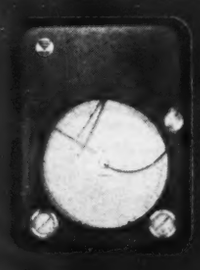

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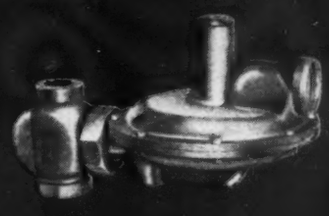

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with relief and breather vents terminating outside. *(Wisconsin).*

Relief vents shall be of sufficient size to relieve the whole capacity of the relief valve. *(Wisconsin).*

All underground piping not in use or planned for use should be disconnected by valve or other means. *(Wisconsin).*

Service pipe shall not be laid in the same trench with other utilities, and where possible, should be laid at a higher level than other utilities. *(Public Housing Authority, Bull. LR-17, V).*

Service trench should be vented to minimize gas seepage. *(PHA Bulletin).*

Service entrances should be made above the floor line where there is a slab floor or unused or concealed crawl space. *(PHA Bulletin).*

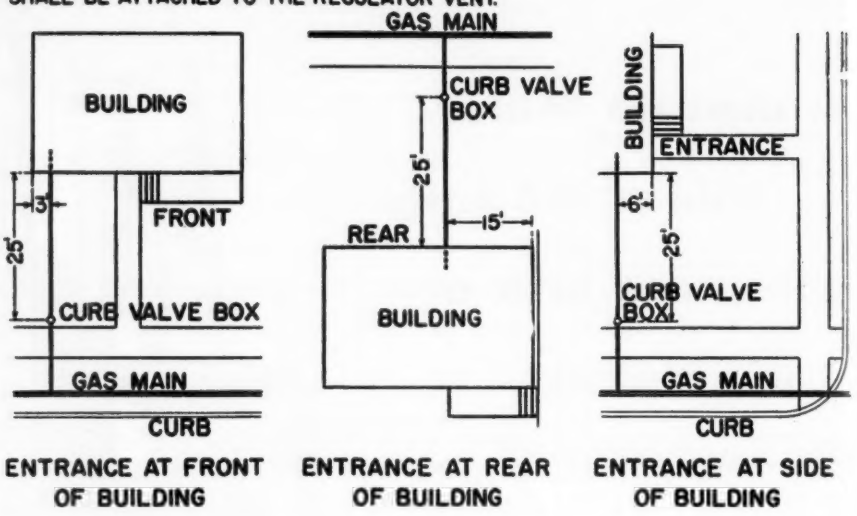
Service pipe should be protected against loosening of pipe joints or pipe breakage by means of swing joints or other positive methods. *(PHA Bulletin).*

The Factory Mutual Engineering Division, Associated Factory Mutual Fire Insurance Companies, Loss Prevention Bulletin No. 11.88, makes some recommendations concerning gas service entrances. In general it recommends an above grade entrance; and where a below grade entrance is required it recommends that the pipe should be encased.

ASA Piping Code

American Standard Code for Pressure Piping (ASA B31.8-1958) deals with gas transmission and distribution piping.

This code undertakes to define and specify the minimum requirements of construction of gas piping from the inlet to a gathering system or the outlet of a manufacturing plant through all the intervening steps to the outlet of the customer's meter. It defines as a gas service that pipe which runs between a main and a meter. It also defines high pressure as being a pressure greater than that supplied to a customer's appliance.



Typical outside shutoff locations, using curb valve boxes.

The code recommends that main connections be made at the top or side. On steel mains, connections may be made by welding or by using a service clamp or saddle; and on cast iron mains, connections may be made by drilling and tapping the main. The diameter of the tapped hole in cast iron pipe should not exceed 25% of the nominal diameter of the pipe except that 1¼-in. taps are allowed in 4-in. pipe.

Concerning the service pipe, the code requires steel pipe be used for all services less than 6-in. in diameter and that when cast iron is used for larger diameter services it should not extend through the building wall. Either welded joints or compression fittings should be used in all services. Cast iron pipe should never be threaded, but may be joined with caulked, mechanical, or flanged joints. A minimum cover of 12-in. in private property and 18-in. in streets and roads is specified for steel pipe.

Service Location

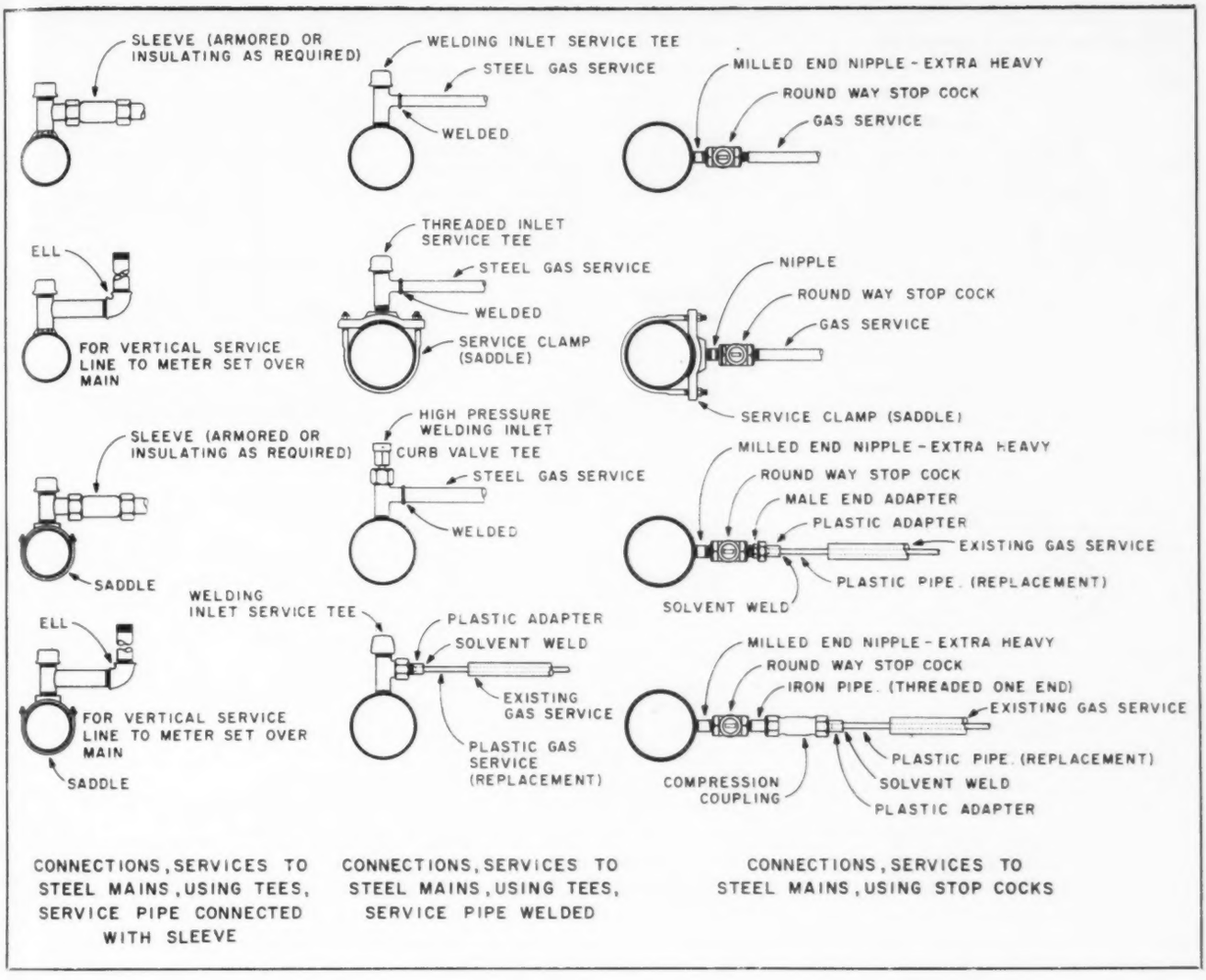
The service location is determined by the meter location and location of the main from which service is to be run. Service line should follow most practical and economical route from main to meter. Consideration should be given the possibility that the service line might conflict with existing obstructions or proposed structures that might result in later relocation of all or part of the service.

ESTIMATED DEMAND OF GAS APPLIANCES IN CU FT PER HOUR
(1000 Btu Per Cu Ft Gas)

Appliance	Cu Ft/Hr
Air conditioning units:	
3-ton, cooling	72
3-ton, heating cycle	120
5-ton, cooling	112
5-ton, heating cycle	120-180
Domestic Gas Range:	60-75
Storage Water Heaters:	
Up to 30-gal tank	33
40 to 50-gal tank	50
Instantaneous Coil Water Heaters:	
Capacity 2½-gal per minute	110
Capacity 3 -gal per minute	138
Capacity 4 -gal per minute	176
Capacity 6 -gal per minute	264
Capacity 8 -gal per minute	352
Gas Refrigerator	4
Radiant Space Heaters:	
5 Radiants	11
10 Radiants	22
Steam Boilers, Per HP	45-50
Gas Engines, Per HP	8-11
Gas-Steam Radiators, per section	2
Wall Heaters, per tube	12

Appliance	Cu Ft/Hr
Built-in Appliances:	
Standard top burner, per burner	9
Giant top burner, per burner	12
Oven	12-22
Broiler	12-22
Gas Lights, per light	3-5
Restaurant Equipment:	
Coffee Urns, 1-gal capacity	11
Coffee Urns, 2 to 4 -gal capacity	17
Coffee Urns, 5 to 8-gal capacity	23
Coffee Urns, 8 to 12-gal capacity	39
Waffle Iron	13
Cake Griddle	17
Steam Table, per burner	17
Toaster, 6-slice size	22
Toaster, 9-slice size	35
Toaster 20-slice size	53
Commercial Ranges:	
4 Top burners, 2 Oven burners	165
6 Top burners, 2 to 4 Oven burners	264
Clothes Dryer	18-20
Space Heating:	
Warm Air, Per room	20
Steam or Hot Water, per room	30

LOAD FACTORS:
Domestic gas appliances plus space heating, **use 90% of total**
Space Heating only, **use 100% of total**



CONNECTIONS, SERVICES TO STEEL MAINS, USING TEES, SERVICE PIPE CONNECTED WITH SLEEVE

CONNECTIONS, SERVICES TO STEEL MAINS, USING TEES, SERVICE PIPE WELDED

CONNECTIONS, SERVICES TO STEEL MAINS, USING STOP COCKS

Method of construction should also be considered. Sometimes moving the service a few feet one way or another can result in considerable savings, eliminating necessity for boring or hand trenching, etc.

Before a service line is constructed, all right of way required should be obtained. If service line crosses property to serve customers not located on said property, a properly written and executed right of way agreement should be obtained from parties having equity in the property crossed.

Service Facilities

Service shutoffs should be installed upstream of the meter and/or regulator. Outside shutoffs shall be installed on services operating at a pressure greater than 10 psig, on all services 2 in. or larger, and on all services supplying buildings where large groups of people assemble.

Underground steel services when installed below grade through the outer wall shall be encased in a sleeve or otherwise protected. The pipe or casing should be sealed at the point of entry. When it is necessary that a steel service be installed under a building it must be encased in a gas-tight conduit extending into a normally accessible part of the building where it shall be sealed.

Service regulators shall have breather vents and relief vents when required. Such vents shall terminate outside in rain and insect proof fittings.

Main Connections

The principal variable in the decision as to the type of main connection to make with cast iron mains is the size of main. The size of main generally limits the size hole that may be drilled and tapped without some sort of reinforcement.

With the exception of 4-in. cast iron pipe, the maximum tap diameter is 25% of the main diameter. For 4-in. pipe 1¼-in. tap is permissible.

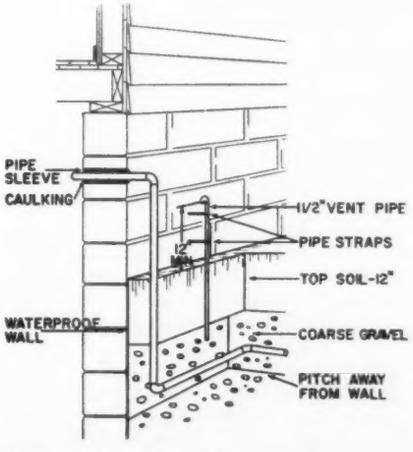
When the size or condition of a main is such that a direct tap cannot be used, some means of reinforcement is required. There is some slight preference for a clamp over a sleeve.

Either single swing joints or rigid connections can be used. Malleable iron fittings are generally used, although brass fittings serve equally well. A wide range of coating materials can be used in field application to these fittings.

Main fittings are not usually insulated from cast iron mains, but the fittings are generally insulated from the service pipe.

The design of main fittings does not usually vary with design pressure. Where mains carry higher pressure, some type of shutoff is often used in the main fittings.

When tapping high pressure cast iron mains, the tap size is usually much smaller than the maximum allowed.

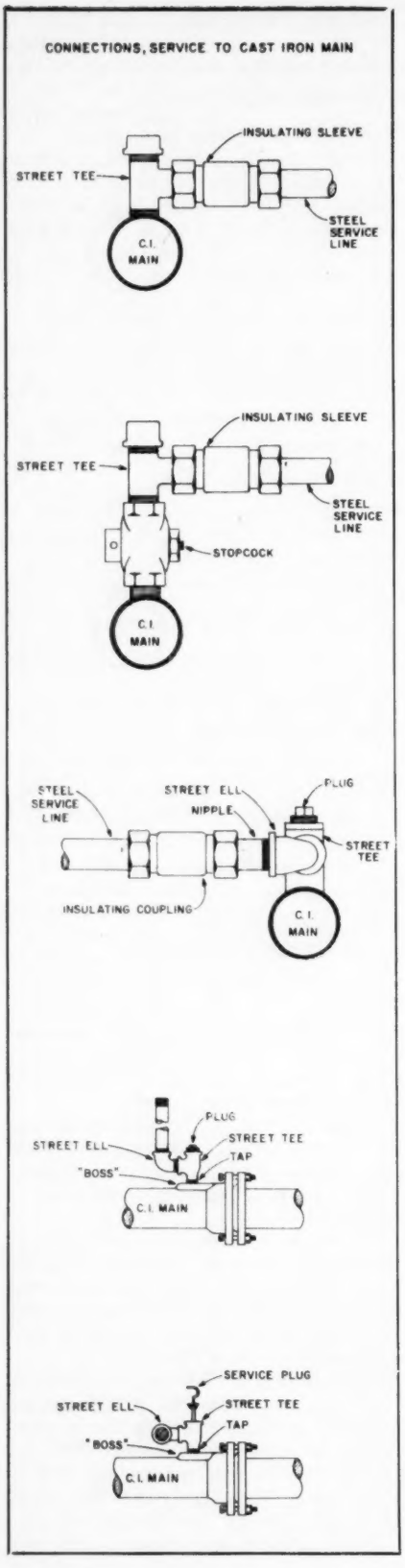


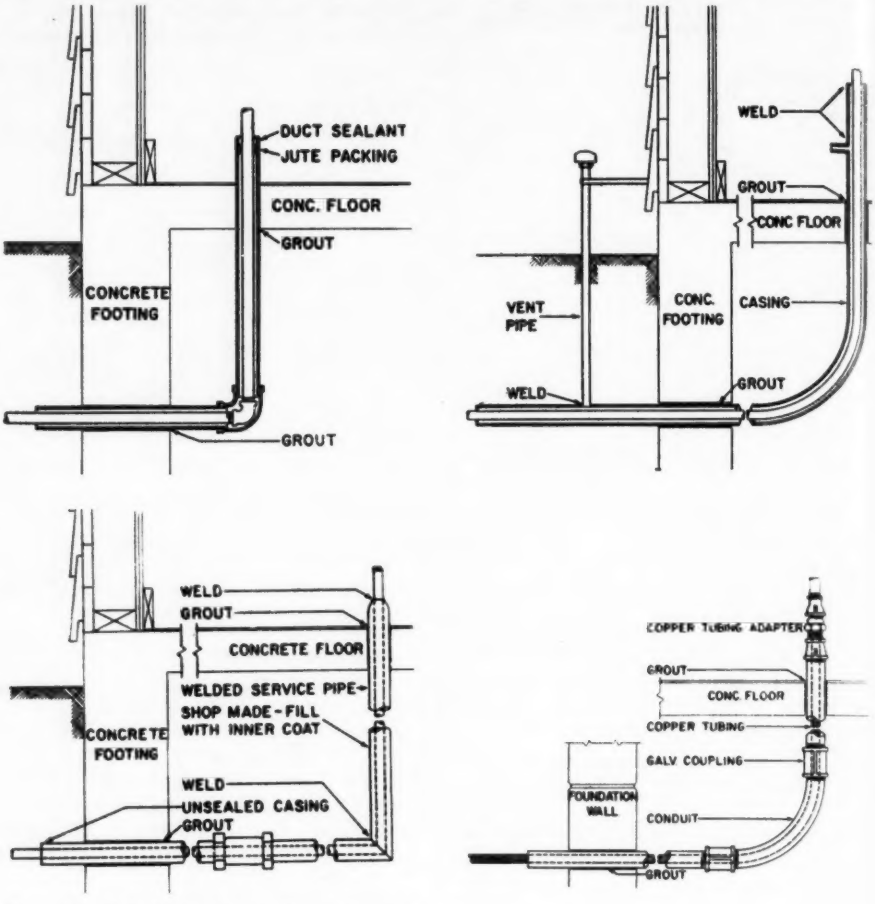
Venting of service trench.

Methods of Joining

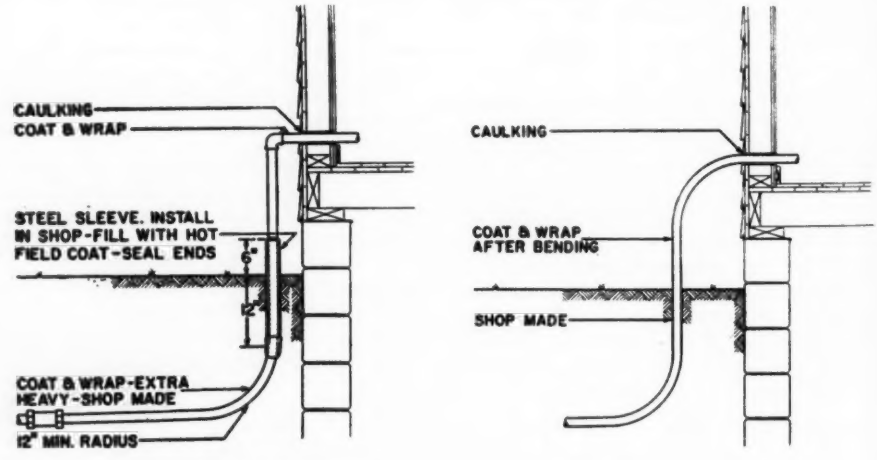
On steel mains and services, welding is the preferred method of joining. Most companies connect fittings to mains by welding. Some make use of a saddle, while others make a joint with a compression or screwed fitting. The choice depends on pressure and individual preferences for types of materials used.

Since service pipe is not continuous,





Examples of below-grade service entrances.



Types of above-grade service entrances.

lengths must be joined in some fashion. Most companies specify welding, while some use compression or screwed fittings.

Service fittings are generally protected from corrosion, using grease, asphalt, or coal tar enamel coatings, generally with a glass wrapper or asbestos felt wrap. In some cases, a galvanized metal coating is used.

Cathodic protection is generally provided, and this is assisted by the fact that welded joints by their nature are electrically continuous.

Where plastic service pipe is used, a standard connection to the main is made first, and the plastic pipe is connected to the main fittings by using an adapter. The plastic pipe lengths are joined by solvent welding. Reinforcement inserts are sometimes used at the joints, depending upon individual company perference.

In all-plastic pipe systems, where mains are of plastic pipe, special plastic service connection fittings (saddle plus tee, etc.) are used. The service line may be directly solvent welded to the service connection.

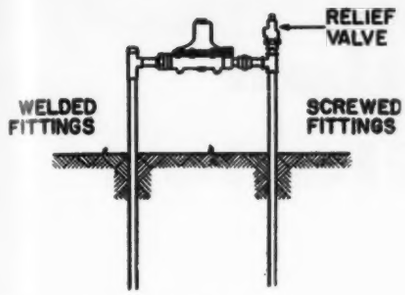
Plastic services do not require additional coatings and wrappings or cathodic protection.

Service Installations

In most cases, companies own the entire service installation.

Depth of service lines varies from 24-in. to 18-in. at the main, and generally is 18-in. deep at the building wall.

Some type of outside shutoff is required by most companies. These shutoffs are usually located between the street and



Typical regulator installation.

sidewalk. Where there is an outside meter, the shutoff may be located above ground on the riser.

Building Entrances

Depending upon the design of the house and the gas service, the entrance into the building occurs either above or below ground. Mostly, the above ground entrance is associated with outside meter sets or basementless houses, and is not protected with anything other than the coating material. When the pipe enters the building wall it is protected either with a casing, or by being coated and wrapped. Some companies believe that extra protection is unnecessary.

The below ground entrance requires that a hole be drilled in the foundation wall large enough to accommodate the service pipe. After the pipe or casing is installed it is sealed into the building wall with either a cement grout, some type of caulking material, or tar.

Current building construction practice tends to the basementless or slab type of building. Many companies do not allow gas service pipe to be installed in the crawl space or beneath the building, while others require that the service pipe be encased. Another way in which the problem can be circumvented is by running the pipe up the outside wall to the eaves, thence in the attic to the location of the drop to the meter set.

Swing joints are used on the service and are quite prevalent on inside risers. Cold bends are allowed by most companies.

Most companies insist on running the gas service the shortest distance from the main to the house. Almost as many, however, permit the use of laterals in laying the pipe. The minimum distance between the building wall and a parallel service pipe is usually specified as one foot minimum distance.

Meter Installations

Few companies install no meters outside, while some install all of their meters outside. Outside sets are generally made because of the construction of the house, the pressure on the service, or if the customer desires an outside set. Many of the outside sets are protected by a metal, plastic, or wooden box.

Most companies that make inside meter sets have specifications as to the location of the meter and its relation to other utilities, heating equipment, and accessible locations.

Both tin-case and hard-case meters are used. The location of the meter, service pressure, and flow rate are reasons given for specifying one type of meter over the other. Generally, meter piping is all screwed fittings. An insulating fitting is often incorporated in the piping. This insulating fitting serves to separate the gas piping from the other underground utilities. The iron body brass core stop cock is the preferred shutoff for meter set use.

Regulators

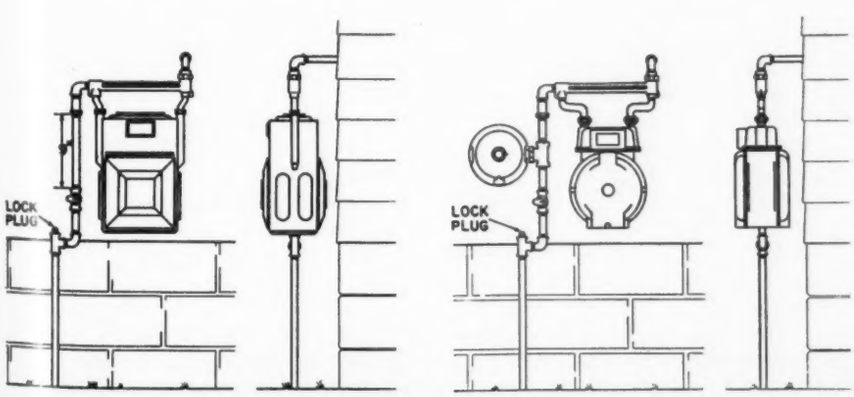
When the distribution pressure is such that a pressure regulator is required it generally is incorporated in the meter piping. Generally, this service regulator has a ¾-in. body, an orifice, from ¼ to ⅜-in. in diameter and about one-half are equipped with an internal relief valve.

The type of relief can be either a mechanical or mercury seal.

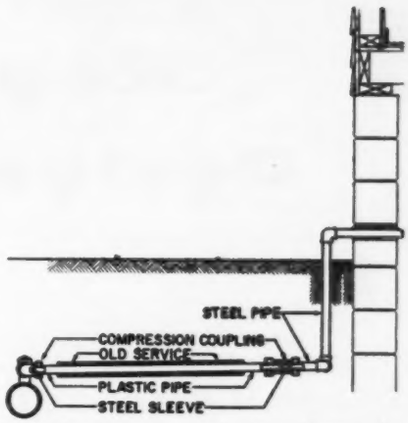
At some pressure levels two regulators are required to reduce the gas pressure to a utilization pressure. Most companies require double regulation when the pressure exceeds 50 psig. Since most of the companies do not permit a pressure greater than 25 psig inside the building, the first cut regulator must be located outside the house. The first cut regulator serves to cut the distribution pressure down to between 5 and 10 psig.

Relief valves are required on all services equipped with regulators by most companies. Some install relief valves on services supplying public buildings. Pressure is usually the criterion for specifying the use of relief valves.

Another safety device recently introduced is the pressure and/or temperature shutoff.



Typical outside meter sets. At right, with regulator.



Typical service renewal using plastic pipe insert.

Service Maintenance

Generally, the preferred method of preserving service information is keeping card files by location, usually showing a sketch of the installation and a bill of materials. Only a few companies have a formal program of service replacement. The age of the service, failure of the service, and leakage survey are the principal reasons for service replacement. There is very little agreement on the anticipated life of a service but most expect at least 40 years.

Actual maintenance of services includes inspection, testing, cathodic protection, repair, and replacement of the component parts of the service line.

All service lines and connections should be given systematic periodic leakage surveys and tests to determine that they are functioning properly and are adequate from the standpoint of public safety.

Types of surveys used include gas detector surveys, bar test surveys, vegetation surveys, pressure drop surveys, and soapsuds testing on exposed pipe and fittings.

Curb boxes and curb cocks should be inspected and tested to determine that they are accessible, properly aligned, and in good working condition.

Whenever the condition of a service line has deteriorated to a point where it should not be retained in service, it should be repaired or replaced as soon as possible.

Repairs include application of clamps, weld patches, or possibly use of the new epoxy materials for patching. Badly corroded services are replaced with new pipe or renewed with inserts of plastic or copper tubing.

Copper has been used for some time by many companies for insert renewals. Generally, the copper is connected to the steel pipe by using insulating compression adapters. Lengths of copper tubing are connected by sweated or solder joints. The copper insert should be insulated at each end — from the steel main and from the meter set.

Plastic tubing is also used for service renewal inserts. Adapters are used to connect the tubing to the steel pipe at the main and the meter set. The old steel or iron service pipe is used as a casing to protect the tubing. Only insulating requirement is that the old steel or iron pipe be insulated from the main and the meter set. ★ ★ ★

Regulator Station Design and Ventilation

THE pattern by which mains are installed, their age, load distribution and density, geographical conditions, etc., play an important part in selecting a location for a district regulator.

Exposure to traffic, both pedestrian and vehicular, exposure to surrounding structures in the event of the operation of safety devices, location of vent stacks, if necessary, and conformance of structures to the appearance of surrounding property should be given careful consideration in the selection of the actual site.

It is generally agreed that private property would be ideal but for various reasons, such sites are seldom available at the most desirable vault location. The survey revealed that approximately 40 per cent of the stations were in parkway areas, 24 per cent in the street itself, 18 per cent in sidewalk space, and 18 per cent in private property. Over 80 per cent of the stations were made below ground. The majority of those above ground were generally situated at a company plant.

Some of the reasons expressed for the preference of the parkway locations are given as follows:

1. **Ease of access**
2. **More accessible for ventilation and operation**
3. **Better working area**
4. **Property rental or purchase unnecessary**
5. **Less subject to surface water flooding**
6. **Work performed outside of traffic hazard area**
7. **Less subject to interference from street widening or grading work**
8. **Less conspicuous**

Local ordinances do not, in most instances, restrict vault locations. A few companies reported that approval had to be obtained from specific governing bodies before a regulator station could be installed.

Size of Station

In the past it has been the practice to house all parts of a regulator station in a single structure. Now, with the trend toward the segregation of valves, regulators, safety devices, etc., smaller underground stations are being used. According to the code, ventilation of a vault is not required if the internal volume is less than 200 cu ft. (This provision does not apply in some states where ventilation of all underground structures is mandatory.)

A vault measuring 5 ft by 6 ft by 6 ft is within this limit and provides ample room for most equipment and servicing of this equipment, provided the valves are installed outside the vault. Because of its small size, it would appear that less maintenance would be required, vent stacks may be eliminated if desired, and, in areas of subsurface congestion, it would be less difficult to select a location for the vault.

A variety of over 20 different sizes of underground structures was reported as being in use at the present time.

Construction

Various forms of construction are used for regulator stations. The following tabulation will give some idea as to the preference of one over another for both underground and aboveground stations. These percentages are a summary of the totals reported in the questionnaire.

EDITOR'S NOTE:

In 1953 a task group was appointed by the Subcommittee on Distribution Design and Development (of the AGA Operating Section's Distribution Committee) to study regulator station design and ventilation. It was thought that, if the practices of gas companies could be reviewed and reported on, some ideas on the different phases of construction might be helpful toward the improvement of present stations or in the development and the design for future construction.

The group as appointed, consisted of Marshall S. David, development engineer, Boston Gas Company; T. C. Wray, chief engineer, Nashville Gas Company; and John F. Schuldt, engineer of distribution design, The Peoples Gas Light and Coke Company, chairman.

At the time this group was formed, ventilation of regulator vaults had become an item of more than usual interest. Its first investigation therefore dealt with vault ventilation and an interim report on it was given at the Distribution Conference held in Montreal, Canada, in 1954.

The next step was accumulation of information pertaining to the design, construction, etc., of regulator stations. A questionnaire was sent out and over 80 replies were received from companies in 35 states and Canada, giving a good geographical coverage. A preliminary report was presented at the Cincinnati Distribution Conference in 1955.

During the period this group has been working, the American Standard Code of Gas Transmission and Distribution Piping Systems was completed. Section 849 covered the item of vaults and undoubtedly has or will affect the design of regulator stations. It would be well for the design engineer to familiarize himself with the several provisions in this section and use them as a guide in the future. A number of companies reported that changes would be made in their installations to conform to the code.

It has not been the intent of this group to make any specific recommendations. This report shows what is being done in general but, the final decision on any installation still remains in the hands of the individual company.

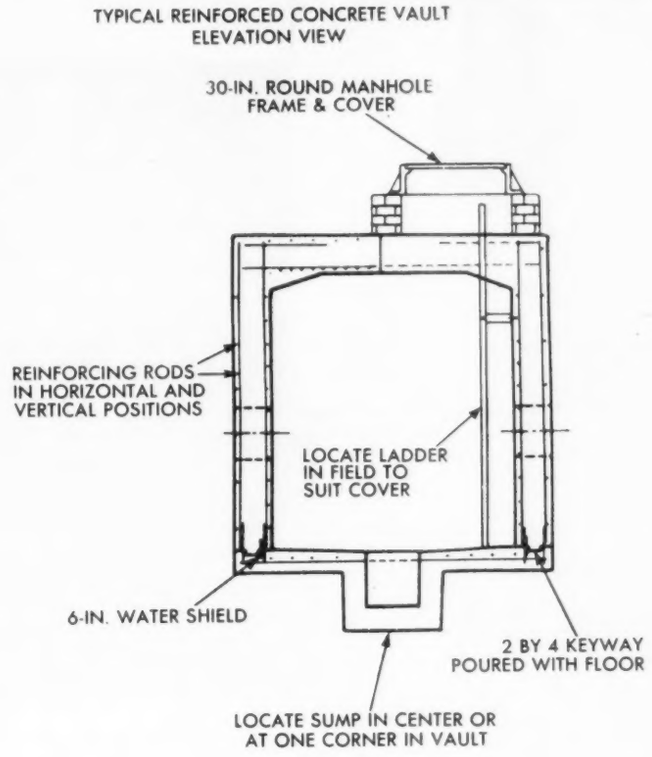


FIG. 1.

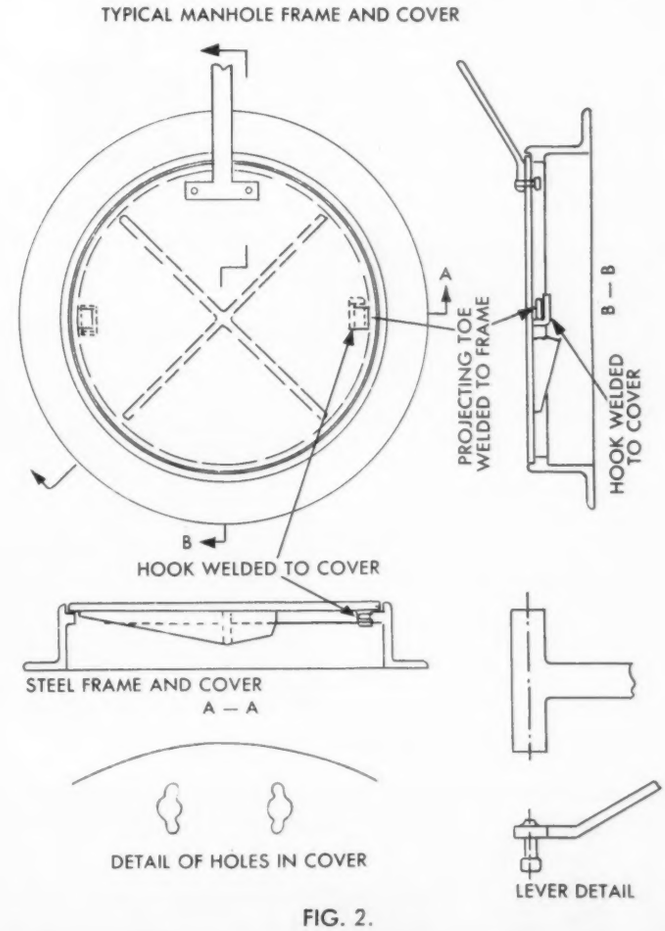


FIG. 2.

Type of Construction	*Underground Station*	*Aboveground Station*
Reinforced concrete	52%	3%
Brick	25	32
Cement block	5	10
Prefabricated steel	8	—
Sheet metal houses	—	31
Precast slab construction	8½	—
Wood	1	9
Open pits—guard rail barrier	½	—
Open shelter—roofed only	—	10
In open—no shelter	—	4
Other miscellaneous	—	1

As shown in the tabulation, the reinforced concrete vault is favored in underground stations. There is little doubt that a concrete vault, properly reinforced and waterproofed, makes an excellent structure. It is easily formed and, with the use of a ready mixed concrete, the pouring problem has been simplified. A 1-2-4 concrete mix is common for this type of vault.

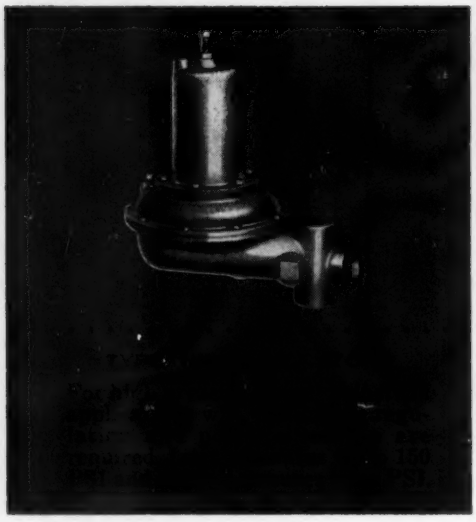
Fig. 1 shows an elevation of a typical vault with some of the features which may be considered in the design. These may be adapted to any vault, regardless of the type of construction used.

Should there be doubt as to the structural requirements for design, or where local regulations do not specify structural limitations, the specifications as set forth in the code may be followed. Section 849.1, paragraph a, states in part that, "the roof slab or cover shall be designed to carry a 15,000-lb wheel load distributed over a contact area of the road surface 15 in. in diameter. The walls shall be designed to resist a uniform horizontal pressure of 250 lb per square foot without damage."

Because of increased interest in safety, load density, and the installation of larger sized regulators that could over-pressure a system, a greater use of monitor regulators and other safety equipment is being made. Gas companies are installing more vaults than heretofore and, therefore, are inclined to make a simplier type of structure than in the past.

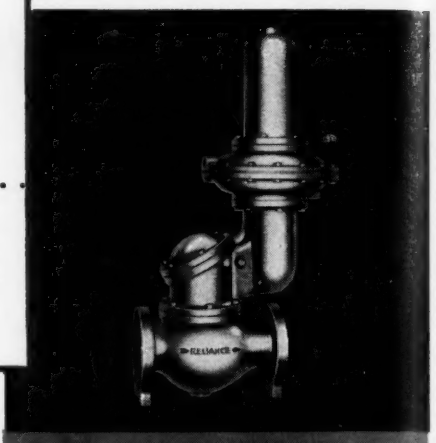
The size of new vaults is also being reduced to avoid the need for providing ventilation. No decrease in the design strength of the new vaults should be tolerated because of the simplification and reduction in size.

In many instances, a station designed for parkway or sidewalk use is of much lighter construction than one designed for the street. It is true that a street vault is subject to much heavier loading, but what is there to prevent the accidental passage of a heavy vehicle over a parkway area? Failure of the lightweight vault as a result of a sudden overload could be serious. It



TYPE "DV" & "RV" VALVES

Relief, back pressure and differential valves for liquids or gases in refinery, gasoline plants and hydrocarbon distribution installations. Maximum relief settings 125 and 225 PSI.



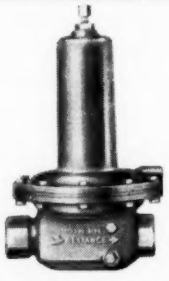
TYPE "CBV" OFFSET & DIRECT CONNECTED VALVES

For transmission, distribution and industrial applications. Weight, spring and pilot loaded. Working pressures in cast iron to 400 PSI, in cast steel or Ductile Relianite to 1200 PSI.

7 Reasons Why You Should SPECIFY RELIANCE® REGULATORS and VALVES

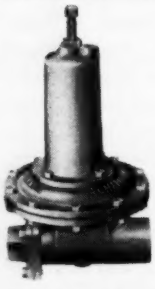
The Most Economical—In Terms of Service

They meet or exceed all the requirements of the Gas Industry—industrial, commercial and domestic.



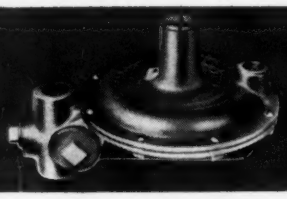
TYPE "HPR" REGULATORS

For reducing, relief and back pressure applications. Inlet pressures to 1000 PSI and outlet pressures from 2½ to 350 PSI.



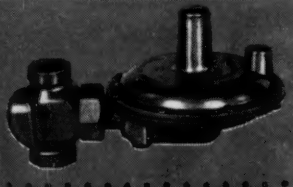
TYPE "HPC" REGULATORS

For high pressure applications. Inlet pressures up to 800 PSI and outlet pressures from 2½ to 75 PSI.



TYPE "HR" & "KR" REGULATORS

These House Service Regulators guard pressures. They incorporate internal relief valves which can be set to relieve at pressures ranging from 8 to 30" WC. Inlet pressures up to 125 PSI. Standard pipe sizes ¾ to 3" inclusive.



SERIES 1400 REGULATORS

Full capacity internal mechanical relief valve model provides maximum safety under most severe conditions. Prevents dangerous downstream pressure even if regulator fails wide open.

WRITE FOR BULLETINS CONTAINING COMPLETE SPECIFICATIONS

AMERICAN AMERICAN METER CO MEASUREMENT ENGINEERS **RELIANCE**

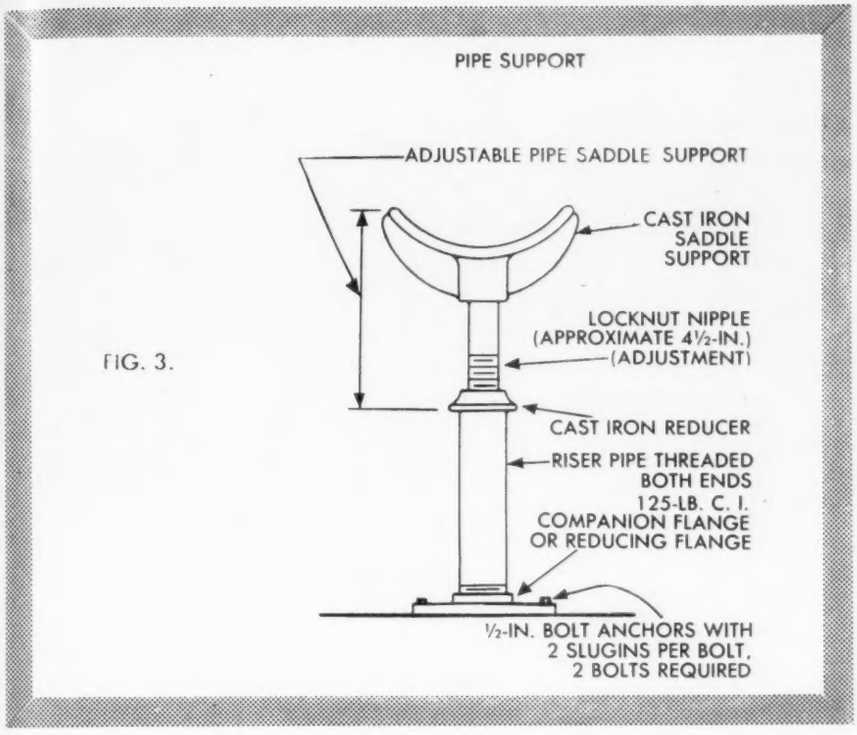

PIPE SUPPORT
ADJUSTABLE PIPE SADDLE SUPPORT
CAST IRON SADDLE SUPPORT
LOCKNUT NIPPLE (APPROXIMATE 4½-IN.) (ADJUSTMENT)
CAST IRON REDUCER
RISER PIPE THREADED BOTH ENDS
125-LB. C. I. COMPANION FLANGE OR REDUCING FLANGE
½-IN. BOLT ANCHORS WITH 2 SLUGINS PER BOLT, 2 BOLTS REQUIRED

FIG. 3.

has been the practice of some companies to install all vaults in public right of way designed for maximum load conditions. In using a smaller vault the difference spent in time and material in construction of a well designed structure as compared to a lightweight one becomes negligible.

Ample room should be left between the top, the roof and the ground level to allow for any alteration of the surface grade which may occur as the result of street paving, widening projects, regrading work, etc. If the frame of the manhole cover is equipped with a telescopic type of neck, adjustments can be made provided the vault roof is installed at the required elevation to permit the adjustment. A good cushion between the roof and pavement is also helpful in lessening the effect of the impact of vehicular loads on a vault.

It should be remembered that a regulator station should be designed to provide safe and desirable working conditions for personnel and with a view toward eliminating excessive maintenance costs.

Covers

Four types of covers primarily used on underground structures are the round cover; the square or rectangular cover; the full opening cover, which also serves as the roof; and the sectional cover, which, although it serves as a roof, may be opened in sections as desired.

The round cover is favored over the others by a large majority. There is no chance that a round cover will accidentally fall into a pit, as is possible with the square or rectangular cover. The maintenance of hinges, as is necessary on all hinged covers, is eliminated. The ASA code requires that whenever an opening is to be situated above equipment which could be damaged by a falling cover, a circular cover should be installed or other precautions taken.

Reactions to the requirement of locks on covers was indifferent. In most instances, the weight of the cover is assumed to be sufficient to prevent tampering. Some covers are bolted in place and locks are used on others. Fig. 2 shows a simple locking arrangement which may be adapted to any round cover. Shifting of the cover in a circular manner locks the cover in place.

Some use is made of a seal cover in the neck of the manhole. Its purpose is to seal off the vault as well as to prevent surface water or other debris from entering the manhole.

In selecting a cover, care should be taken to see that it is large enough to permit the passage of equipment and fittings for installation or during repairs, and to permit ingress and egress readily.

One or two covers are commonly used per vault. Some companies use a combination of a round and square cover. More than one cover is used by some companies to vent a vault quickly before entering it.

Drainage

With the abolition of sewer connections by the ASA code, the problem of drainage is limited to either a sump or crushed stone type of floor. Placement of the sump is a matter of choice but it should be placed in an accessible position for pumping and where it will give minimum interference with the maintenance of the equipment. A common location is the corner of the vault in back of the ladder.

A perforated cover plate may be supplied if the sump is located where someone may accidentally step into it. It is the practice of a number of companies to place the sump in the center of the floor where the additional space of the sump is used when overhauling regulators that have a bottom opening.

Some use is made of a suction line consisting of 1½-in. pipe extending from the bottom of the sump to the surface of the vault to permit pumping without removing the cover.

Ladders

Most ladders used are steel and are fastened permanently to the wall. A few companies reported using wood or aluminum ladders. It is felt that having a ladder fastened to the wall is good practice as it provides the only means of exit if an emergency arises. If a removable ladder is used some type of hanger or stop should be used to prevent it from slipping.

Pipe and Fitting Supports

Brick or concrete piers, pipe or wood supports or hangers from the roof are used to support the valves, regulators, fittings, etc., in the station. Although all of the types mentioned may serve their purpose satisfactorily, an adjustable pipe support may have some advantages (see Fig. 3).

This type of support may easily be removed while working on the equipment, or adjusted to proper height — whatever the need may be.

Painting

Opinion on the painting of the interior of the structure and piping for both aboveground and underground stations is divided. It is pointed out that better housekeeping conditions existed in painted stations. A good waterproofing paint, properly applied to concrete or masonry surfaces, also helped to keep underground stations drier.

Painting of the piping and equipment in a station will add to its appearance. Some companies use a color code in their painting. As an example, one company used the following color code.

Low pressure — green
Intermediate pressure — yellow
High pressure — red
By-pass lines — striped

Another company paints all inlet piping red and outlet piping blue.

With the additional control piping resulting from the use of safety equipment, the differentiation between the

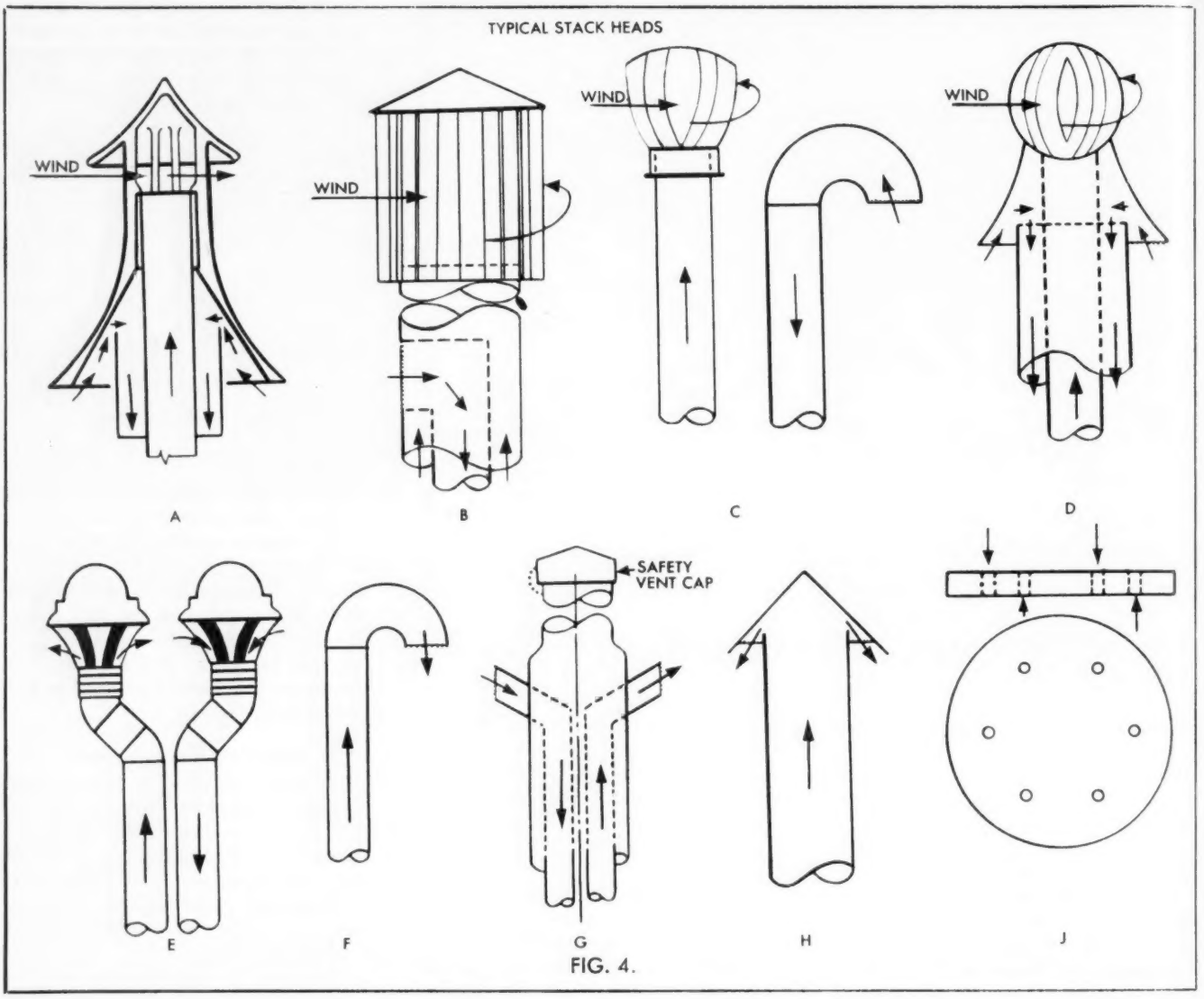


FIG. 4.

piping has assumed a greater importance. Color coding of the piping by companies not using such a system might be given consideration.

Wall Seals

It is important that the entry of piping through the wall in underground stations be sealed in a manner to help prevent the concentration of stresses on the pipe and prevent the leakage of moisture or gaseous products into the station. A preference was expressed for the use of sleeves in connection with masonry or concrete structures.

The sleeve, several inches larger in diameter than the gas main, is installed in the wall at the time of construction. The voids are filled with mastics, yarns, etc., and in some instances a reducing coupling is used. On steel vaults, the main is either welded to the wall or a coupling is used, with the center ring being welded to the wall and acting as a sleeve.

Where no sleeve is used, the wall is formed directly around the main, which has some type of wrapping on it.

Opinion is that strains, caused by vibrations, settlement, or other reasons, are minimized when a wall sleeve is used. Also, if the piping has to be adjusted or removed for any reason, it may be done without disturbing the wall structure.

Miscellaneous

Other miscellaneous items connected with station design may be briefly considered as follows.

Soundproofing. Little need for soundproofing of underground stations was found. Some use of it is made in aboveground stations but as it is usually a local problem it should be resolved by the individual company.

Protective barriers around stations. Only in aboveground stations or open pit construction were barriers used. They consisted of a simple pipe rail or wire mesh type of fence. In residential areas, grounds are landscaped to conform to the surrounding areas.

Electrical facilities. Use of electric equipment is covered in the code under Section 849.4, paragraph c, which states that electrical equipment in vaults shall conform to the requirements of Class 1, Group D, of the National Electrical Code (ASA C1). Electricity is used for lighting and in a few instances for control and equipment operation.

Cathodic protection. The application of cathodic protection is being given more consideration than in the past. More than half of the reporting companies make use of cathodic protection for piping and equipment around a vault. The additional use of steel vaults in recent years has added to this problem. The extent of all protection should be determined by the corrosion engineer.

Costs — There was a great variation in the cost of regulator stations. Prices ranged from a few hundred dollars to several thousand dollars, depending on the type of structure, size, location, etc. It is the responsibility of the design engineer to provide a structure that will be adequate for use at a minimum investment.

Ventilation

When the task group was formed, it was the intention to prepare a sug-

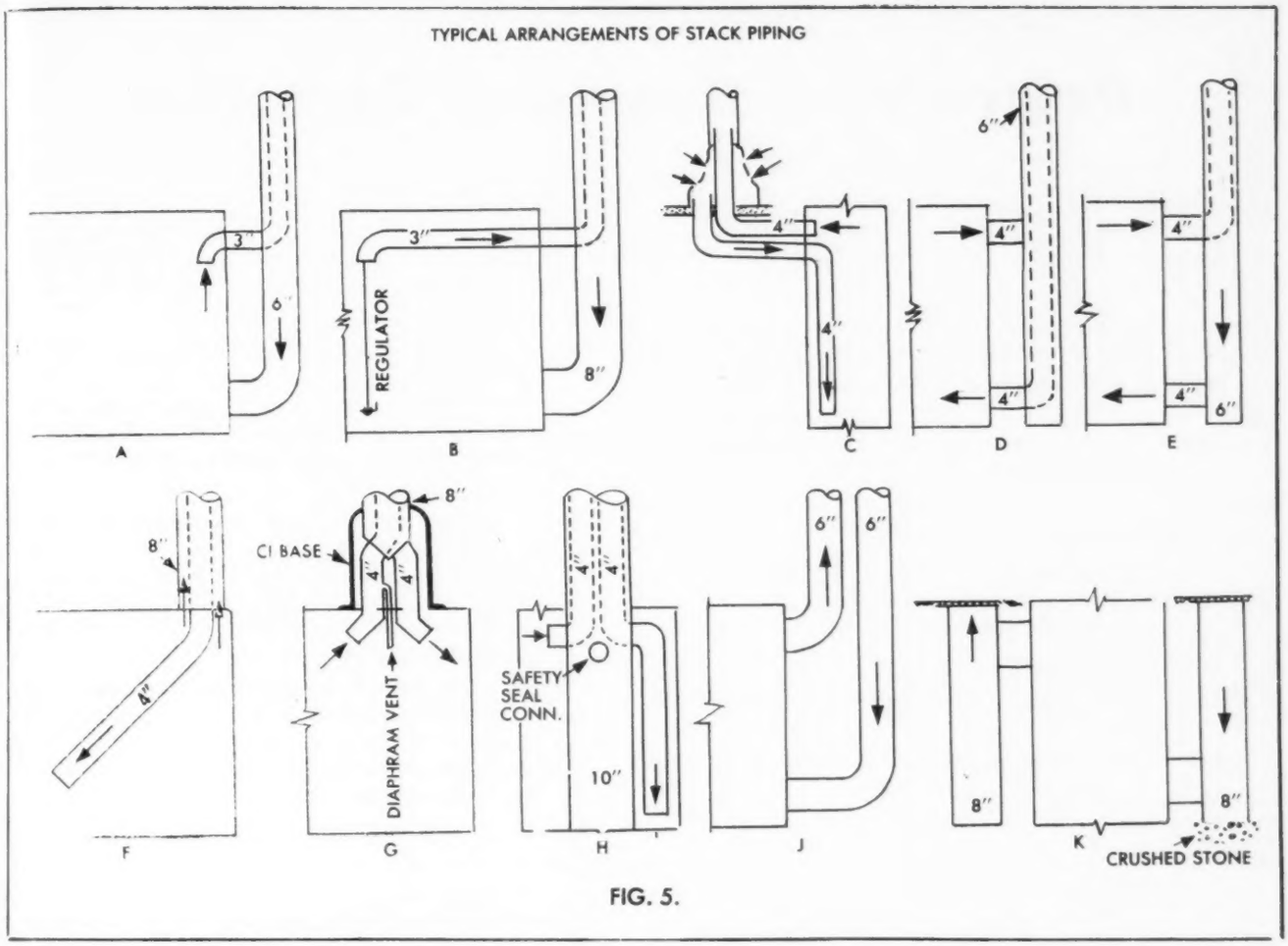


FIG. 5.

gested standard for vault ventilation. A review was made of the work and tests conducted by several companies and the U. S. Bureau of Mines on various types of vault ventilation. This part of the task was resolved through the adoption of the ASA Code. Section 849.3 covers the ventilation of underground vaults very thoroughly. Many of the problems and questions raised by various companies have been answered by the provisions in this section.

Briefly, it states that all vaults should be ventilated where the internal volume exceeds 200 cu ft. Two vent ducts are to be used and should be large enough to minimize the possibility of formation of a combustible atmosphere in the vault. The ventilating effect of a pipe 4 in. in diameter was specified as the minimum-sized duct that could be used. Qualifications for the height of the duct and type of ventilating hood to be used are also given. Vaults having an internal volume between 75 and 200 cu ft need not be ventilated if all openings are properly sealed. Vaults with an internal volume of 75 cu ft or less do not require ventilation.

Questions were asked, at the time the questionnaire was sent out, as to the size of vaults being ventilated, location of vent ducts and objections encountered in connection with the installation of vent ducts.

Vent piping, where used, was either 4-in. or 6-in. in diameter. Many were combined into a pipe within a pipe as illustrated in Fig. 5, illustration G. To overcome the objection of the unsightly appearance of vent stacks, an ornamental standard of some type was used.

Fig. 4 shows the different stack heads presently being used by some companies. Simple heads are represented in F, H and manhole cover J. More elaborate rotating heads are illustrated in B, C and D.

Fig. 5 shows various arrangements of stack piping. Some companies using aboveground gage boxes run piping to this equipment in the vent stacks.

Complaints in better residential areas on the appearance of the vent stacks were overcome in some instances by using a higher vent stack. In other instances where complaints were made it was pointed out that the vents actually were not much different from the utility poles generally installed throughout residential areas. Other companies reported the necessity of having to obtain permission of the municipalities to make such installations.

Regardless of the type of stack used, care should be exercised to see that they are situated a reasonable distance from structures so no hazard from escaping gas will be encountered.

In most instances the opinion is general that the operation of existing vault structures would continue as in the past because the code was not retroactive. This does not imply, however, that any unsafe existing installation should continue in operation. New structures would be erected to conform to the various provisions of the code.

Safety

Safety of construction and operation should not be neglected. One reply received had this quite appropriate remark to make. "In discussing the design of underground pits, too much stress cannot be placed on the fact that each station is a problem in itself. Safety to the public and personnel, relationship to our distribution system, ground conditions and ease of maintenance must all be taken into consideration."

Insist on a good safe design. Provide the necessary tools and equipment in order that work may be performed in a safe manner. A good, regular inspection program will be a help toward accident-free operation. * * *

Determining Regulator Capacities

A study of the various equations now in use for computing regulator capacities reveals the following seem to be the most practical:

(1) Where the flow is below critical velocity (regulator outlet absolute pressure being more than one half of the regulator inlet absolute pressure): $Q = K\sqrt{h\ p_o}$

(2) Where the flow is above critical velocity (regulator outlet absolute pressure being less than one half of regulator inlet absolute pressure): $Q = \frac{1}{2}\ KP_1$

Where,

Q = Mcf per hour of .65 sp. gr. gas at a base pressure of 14.73 psia

h = Drop in pressure across regulator, psi

P_o = Outlet pressure, psia

P_1 = Inlet pressure, psia

K = Constant, depending on regulator valve size and characteristics.

For convenience, these equations are transposed as follows:

$$Q = K \times \text{Flow Factor}$$

Graphic charts (Fig. 1 through 6) have been prepared whereby flow factors may be read directly, depending upon the regulator inlet and outlet pressures.

The "Flow Factor" (shown on bottom scale) is equal to $\sqrt{hp_o}$, for conditions outlined under equation (1); and is equal to $\frac{1}{2}\ P_1$, for conditions outlined under equation (2).

These flow factors when multiplied by factor "K" (in table) equal the recommended maximum regulator capacity.

From Columbia Gas System Service Corporation.

In attempting to determine "K" factors for practical use for the different regulators in common use, it is necessary to make several compromises and assumptions which are briefly stated as follows:

(1) It is interpreted that the maximum capacity of a regulator is that quantity of gas which a regulator will deliver at a given pressure drop between its inlet and outlet flanges; that is, the regulator body is considered the unit rather than only the regulator valves or any part of the setting.

(2) In developing practical "K" factors for the different regulators, it was found that some regulators have greater valve opening areas than the area of the regulator outlet pipe opening. In such cases, the "K" factors shown in the table are measured to an amount that has been found practical.

(3) These capacity data are based entirely on the capacity of the regulator main body and do not take in account variations in outlet pressure resulting from other causes, such as friction, lack of operative power, etc., which are common in the older type of regulator.

The table sets forth practical "average values" for K, which are believed to be accurate and safe for the purpose intended. In most instances they are as accurate as many of the other variables involved, such as the estimated inlet and outlet pressures, etc. Where more accurate values of "K" are available, such as those furnished by regulator manufacturers, obtained from special tests, etc., they may be substituted for those in the table and inserted in the blank spaces provided.

HOW TO DETERMINE REGULATOR CAPACITIES

The following curves and table of "K" factors are a convenient way of determining the capacity of various kinds of regulators. The "K" factors shown are for commonly used types of regulators.

To determine maximum capacity of regulator.

1. Locate outlet pressure on left margin of graph.
2. Trace horizontally to estimated minimum inlet pressure.
3. Trace vertically down and read "Flow Factor" on bottom scale.
4. Maximum hourly capacity equals "Flow Factor" multiplied by "K" factor of type regulator considered.

Example:

Assume: A 6-in. balanced valve, regulator of the older type using flat disc seats, 0.25 psi outlet gage pressure and an estimated minimum inlet gage pressure of 10 psi.

from Fig. 1 — Flow Factor = 12.1

from table, "K" factor = 16.5.

Maximum Regulator Capacity = 12.1 × 16.5 or 199.7 Mcf per hour

To determine the size regulator required when the quantity and pressure conditions are known.

Example:

Assume: A maximum hourly rate of flow of 100 Mcf per hour, an outlet pressure of 100 psi, and an estimated minimum inlet pressure of 250 psi.

Then: From Fig. 4, Flow Factor = 133; therefore "K" Factor required = 100 ÷ 133 or .75. It will be noted from table of "K" factors that a 2-in. regulator having 1-in. balanced valves will have ample capacity.

TABLE OF "K" FACTORS.

Pipe size of regulator	Inner valve	"K" Factors
2 in.	⅜ in. Balanced valves	.5
2 in.	1 in. " "	1.0
2 in.	Std. " "	1.9
3 in.	" " "	4.2
4 in.	" " "	7.5
6 in.	" " "	16.5
8 in.	" " "	27.5
10 in.	" " "	42.0
12 in.	" " "	61.0

These "K" factors are used for the older type regulators using flat disc seats, quick opening regulators limited to ¼-in. valve travel, and for the newer design regulators where the outlet piping is not increased immediately at the regulator.

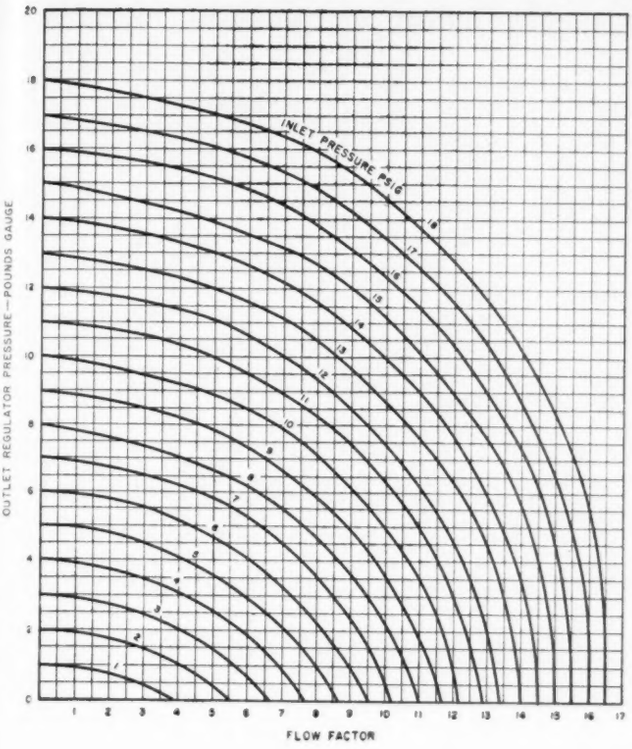


FIG. 1

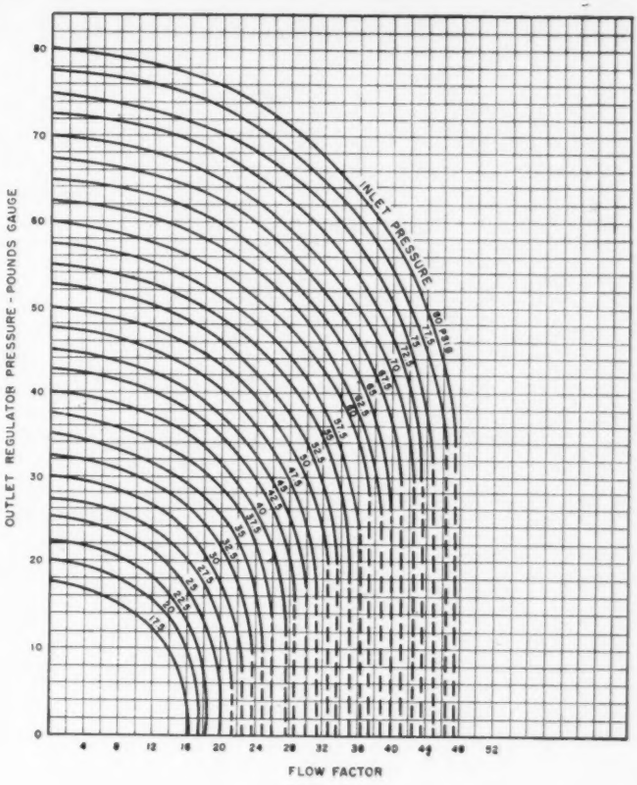


FIG. 2

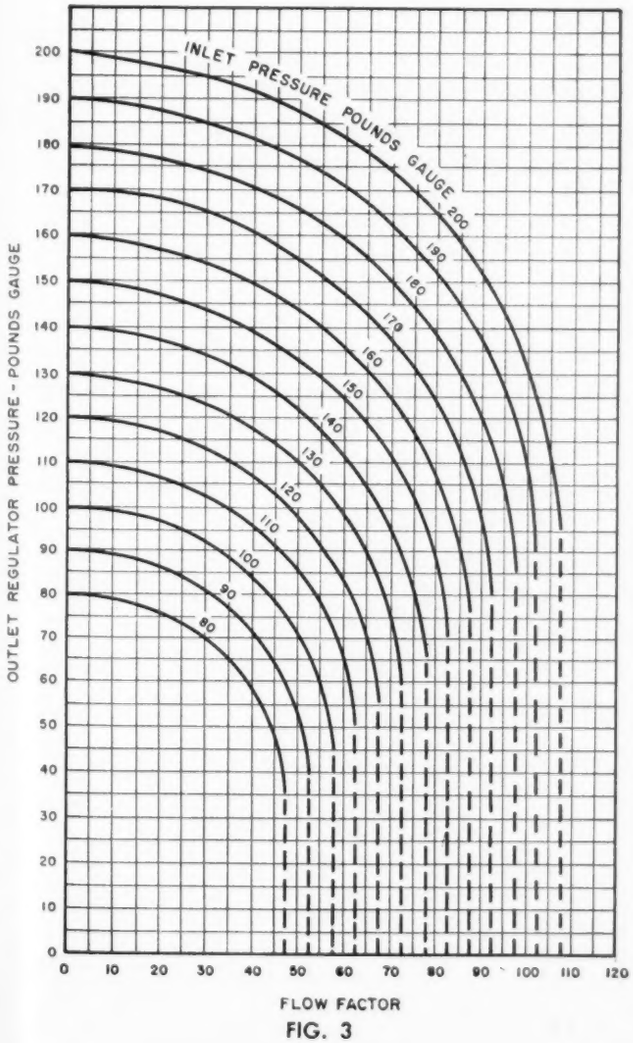


FIG. 3

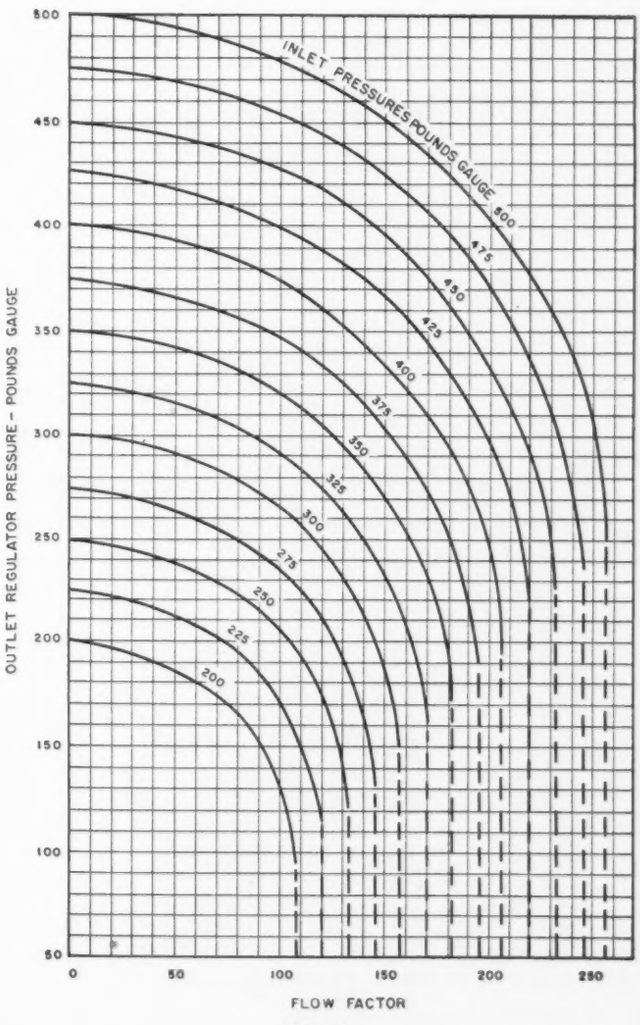


FIG. 4

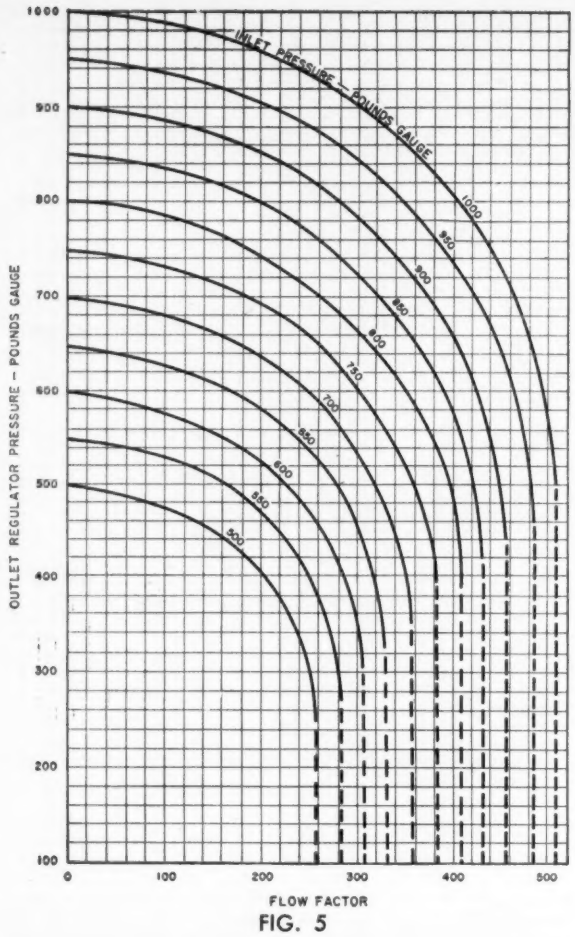


FIG. 5

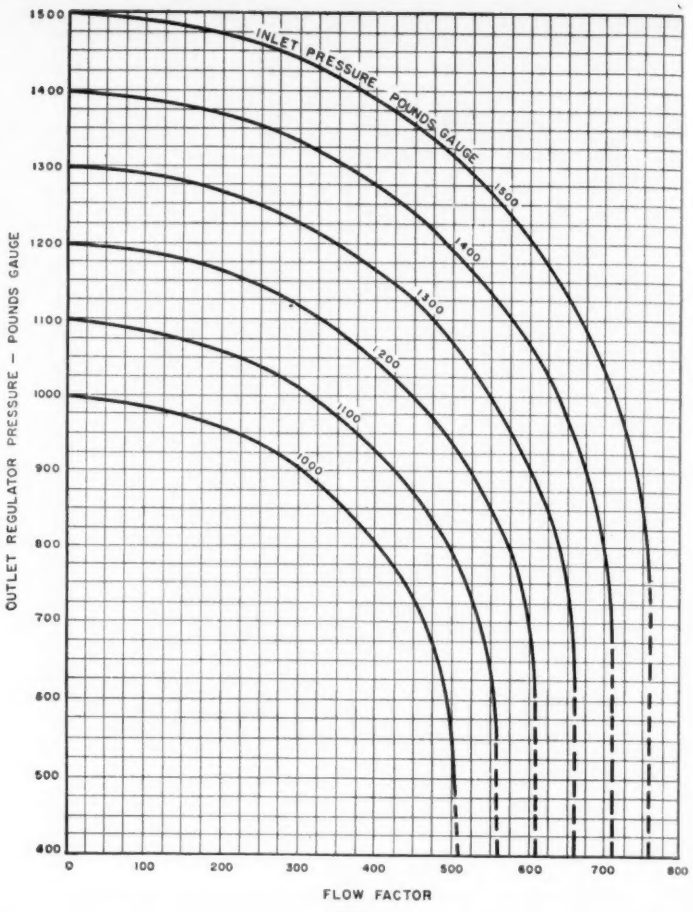
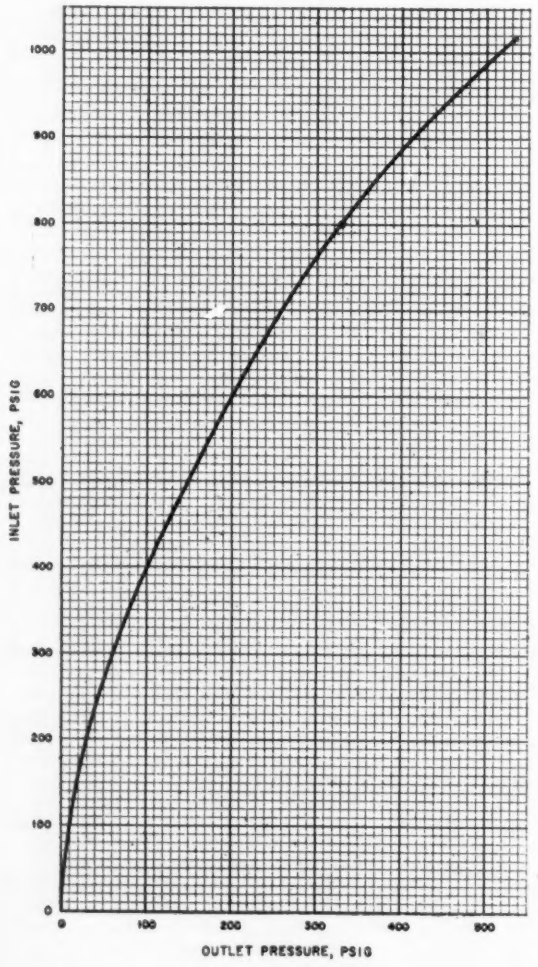


FIG. 6



HOW TO DETERMINE THE NUMBER OF REGULATORS IN SERIES — INCLUDING MONITORING REGULATORS —FOR GIVEN PRESSURE CONDITIONS.

(This does not apply to service regulators).

Explanation:

Case 1: Determine the practical pressure cut for a 700 psig inlet pressure.

1. Locate 700 psig inlet pressure on the left scale of the graph.
2. Trace horizontally to the right to the curve and then trace downward to the bottom scale. Read outlet pressure of 250 psig.

Case 2: Determine the number of cuts required for station where the inlet pressure is 700 psig and the desired outlet pressure is to be 20 psig.

First Cut: 700 psig to 250 psig

Second Cut: 250 psig to 50 psig

Third Cut: 50 psig to 20 psig

NOTE: While the example shows pressure cuts, the same number of regulators may be used, with one or more regulators being used as monitoring regulators.

From Columbia Gas System Service Corporation

How To Solve Regulator Freezing Problems

The reduction of pressure of a gas caused by throttling through a pressure reducing valve establishes a sudden expansion of gas at the outlet of the valve. This sudden expansion sets up a heat transformation, causing the valve body and pertinent piping to be the absorber. Whenever this heat is not sufficiently present in the gas itself, then it must be taken from the immediate environment. In this case, it is the valve body, immediate piping, and soil, if pipe is covered. The temperature reduction for a typical natural gas is approximately 1F for each atmosphere reduction or 7F per 100 psi pressure cut. The effect of this heat transfer problem manifests itself in many ways and can be a source of serious trouble. The two most important problems involved are, (1) internal freezing of the regulator, and (2) external freezing of the regulator body, the immediate piping and the surrounding environment.

Internal Freezing of Regulators

Internal freezing of a regulator occurs when the temperature drop (due to a pressure reduction) causes the gas temperature to reach the dew point of the gas. When this condition is reached, problems can occur from hydrate formation, or ice formation, if the dew point is below the freezing point.

The freezing point depends on the gas composition, water content, and pressure of the gas. There are several methods of combating these problems, such as alcohol injection, heated buildings, and heat exchangers.

Freezing of Surrounding Outlet Piping

The low gas temperature caused by large pressure reductions frequently has serious effects on regulator outlet piping and mains. When the temperature of the outlet gas and piping is 32F and below, freezing of the moist earth covering the pipe causes expansion and heaving. Usually, this action results in damage to building foundations, highways, etc., and imposes high stresses with possible distortion to the piping and regulator setting. On a regulator setting where the maximum flow rate and/or pressure cut is not large, this effect may be unimportant; however, on large regulators with high maximum flow rates, and especially in poorly drained areas, serious damage may result.

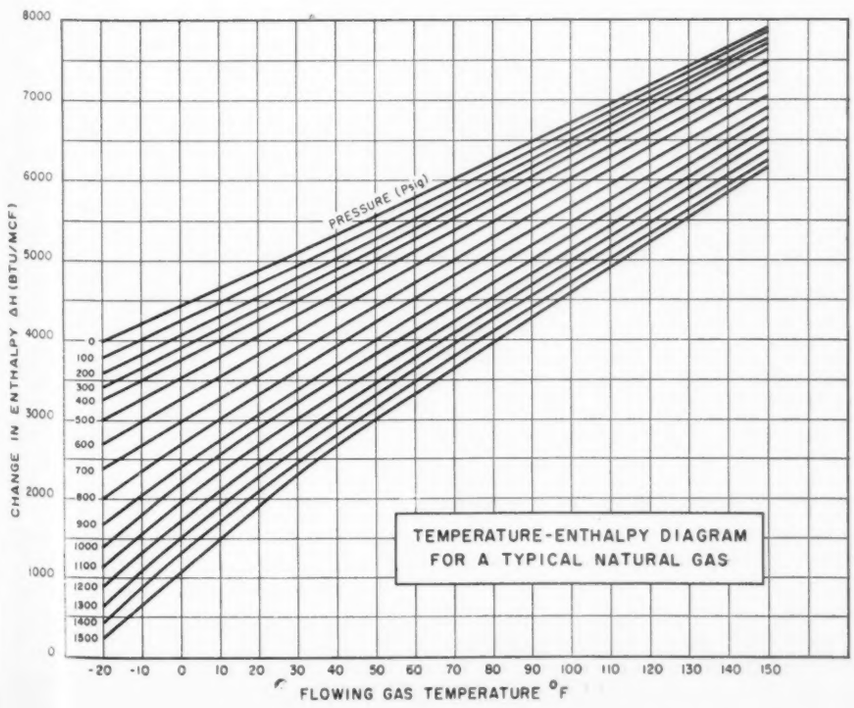
Best experience, to date, indicates that one of the four methods (or a combination of all four in some troublesome locations) may be used to eliminate damage.

1. One method commonly used is to have all underground piping that carries cold gas at 32F or below, surrounded with at least two feet of loose gravel. Care should be given that proper drainage is provided to remove free moisture from the gravel. Particular attention should also be given the corrosive properties of the gravel used.

2. When the regulator setting is in a location that is flat and low without opportunity for drainage, the setting and piping may be elevated above ground or station flooring and outlet piping extended for some distance from the station before being buried. This distance is governed by the surroundings such as railroad crossings, road crossings, or building foundations, and physical limitations of the property.

3. Another method is to insulate the pipe in order to slow down the heat transfer between the pipe and the surrounding earth. Generally, the pipe would be insulated in the immediate vicinity of the regulator where damage may occur, e.g., if the pipe passes under the structure walls, a railroad crossing, or any highway, etc., the pipe would be insulated so that any freezing that might occur will take place well away from the zone where damage may result to the structure or highway. One method of insulation is a sealed casing on which a partial vacuum has been established.

4. If regulator settings are in a location where none of the above methods can be used, then some method of applying heat can be used. Some type of heat exchanger should be installed on the inlet to the regulator setting in order to heat the gas so that it will be above 32F on the outlet of the regulator setting. In a setting of this type, the cost of fuel required for operation of the heater should be considered.



Determination of Base Heating Requirements

If the composition, temperature, and pressure of the gas is known, the heat or enthalpy of the gas can be determined from an enthalpy diagram for natural gas. The amount of heat required to heat the gas can be determined so that the temperature of the gas on the outlet of the setting will be above 32F where freezing of earth surrounding outlet piping is encountered, or the required minimum temperature where internal regulator freezing is encountered.

1. Internal Freezing of Regulators. When internal freezing is involved, experience has shown that it is only necessary to provide sufficient heat to the gas to heat approximately 10 per cent of the maximum regulator capacity to a temperature slightly above the dew point of the gas to prevent liquid water from falling out which might cause freezing or hydrate formation. At flow rates greater than approximately 10 per cent of the maximum

regulator capacity, internal freezing is generally not encountered.

2. Freezing of Earth Surrounding Outlet Piping. The following example illustrates how the base heating requirements for a regulator heater can be determined.

Assume the following:

Flow Rate	20,000 Mcf/day
Flowing Gas Inlet Temperature	67F
Inlet Pressure	1200 psig
Outlet Pressure	350 psig
Dew Point	30F

With reference to the *Enthalpy Diagram*, the inter-section of the 67F line and the 1200 psig curve indicates an initial enthalpy or heat content of 3975 Btu per Mcf. To find the outlet temperature, the intersection of the 350 psig curve with the constant enthalpy line from the intersection of 67F and 1200 psig gives a temperature of 7.5F.

To prevent freezing of earth surrounding the outlet piping, the outlet gas temperature should be approximately 35F. The intersection of the 35F line with the 350 psig indicates an enthalpy of 4700 Btu per Mcf.

Therefore, the heat required to be added to the flowing gas would be:

Heat required = Btu difference × flow per day in Mcf
= 4700-3975 × 20,000
= 14,500,000 Btu per day OR 604,200 Btu per hr.

The temperature to which the inlet gas must be raised can also be determined by the intersection of the 1200 psig curve and the constant enthalpy line at 4700 Btu per Mcf indicating a temperature of 86F.

In using the change in enthalpy diagram, it is assumed that true throttling or Joule-Thompson expansion occurs at the reducing valve and the expansion takes place at constant enthalpy.

How to Select a Regulator

When selecting a pressure regulator based upon an analysis of the operating conditions and requirements, the following points must be considered:

1. Rate of flow, both maximum and minimum, in cubic feet per hour at base pressure conditions.
2. Type of gas and its specific gravity.
3. Inlet pressure, maximum and minimum.
4. Outlet pressure and the desired range of adjustment.
5. Accuracy of controls needed.
6. Pressure build up permitted at zero flow.
7. Type of valves, hard or soft seat.
8. Size of pipe connections.
9. Ease of future repairs and maintenance.

Rate of Flow

The correct sizing of regulators is very important in obtaining the maximum efficiency from a regulator. At normal loads the regulator should be operating at approximately one-half its rated capacity. In most cases, the maximum expected load and the regulator capacity should be very nearly the same. An oversized regulator will have to operate with its valves in an almost closed position, which will often result in erratic control or pulsation of the regulator. In an ideal situation, a regulator should not have to be operated at a flow of less than 10 percent of its maximum capacity. Actually, many regulators must be operated down to almost zero flow. Continuous operation at low flows, however, may result in valve seat cutting, and, on sensitive regualtors, there is more chance that the regulator will vibrate or pulsate.

Type of Gas

On most natural gas, it is desirable to use synthetic rubber material for soft seat valves. On manufactured gas, it is necessary to use leather valve discs. Liquefied petroleum gas is likely to displace standard oil treatment in leather diaphragms resulting in leakage of gas. Special diaphragm treatment or synthetic diaphragms must be used with propane or butane gas.

Inlet and Outlet Pressures

Inlet pressures will affect the regulator type and size. The mechanical structure of the regulator must be such as to withstand the pressure, and moving parts must be constructed so as to minimize any abrasive action due to the high velocity of gas through the regulator. Since, in general, it is desired to have the valve an appreciable distance off its seats during normal operation, higher pressure drop across the regulator means smaller sizes of valves for any desired flow rate.

The range of outlet pressure desired determines the size of diaphragm case. The larger the diaphragm, the more responsive it will be to changes in pressure. Therefore, the largest diaphragm consistent with pressure conditions should be used. For any particular type of regulator, the proper diaphragm size for various outlet pressures is listed.

Accuracy of Control

On large regulators, different types of loading diaphragms can be used depending on the accuracy of control needed. The simplest and most rugged design that will give the necessary accuracy should be used.

For example, the weight or spring-loaded high pressure balanced valve regulator is a simple type of regulator, and should be used where the flow is fairly constant or the outlet pressure can vary about 5 to 10 percent. If better control is needed, the power pilot regulator can be used to load this regulator and obtain constant outlet pressure over a wide range of flow.

Type of Valves

When a complete shut-off of flow is required, a soft seat valve should be used. On high pressure cuts, the valves are subjected to erosion from the particles carried along in the gas stream. In such cases, hard seat valves should be used to help withstand this cutting action.

Size of Connections

In some types of regulators, such as the field and service regulators, the same basic size of regulator can be furnished with various sizes of inlet and outlet connections. In most cases, the sizes of connections is determined by the required regulator capacity.

From Rockwell "Gas Regulator Handbook." Reproduced by permission of Rockwell Manufacturing Company, Pittsburgh, Pennsylvania.

Proof Testing Gas Meters for Accuracy

To arrive at accurate results in proof-testing gas meters necessitates close attention to a great many details. Merely connecting the meter to a prover and passing a small quantity of air or gas through, without strict regard to the following rules, will result in an approximation only and is not a correct proof test.

To proof test a meter accurately the prover must be mathematically correct, perfectly level, duly conterpoised and adjusted so as to give uniform pressure from top to bottom during the movement of the bell in the tank. Provers are commonly adjusted to throw a pressure of one and one-half inches water column. The liquid in the prover, the air or gas in the bell and also the meter to be proof tested must all be uniform in temperature with the air of the room in which the tests are to be made and all these temperatures must be kept uniform during the entire test.

The meter or meters to be proof tested should be brought to the proving room at least five hours or if possible for a longer period before making tests, thereby giving them an opportunity to become adjusted to room temperature. When these conditions have been met, the test may proceed.

Percentage of Error Table

	2 cubic feet passed by meter		5 cubic feet passed by meter		10 cubic feet passed by meter		20 cubic feet passed by meter	
	Prover	Error	Prover	Error	Prover	Error	Prover	Error
	1.80	+11.11	4.50	+11.11	9.00	+11.11	18.00	+11.11
	1.81	+10.50	4.52	+10.62	9.05	+10.50	18.10	+10.50
	1.82	+ 9.89	4.55	+ 9.89	9.10	+ 9.89	18.20	+ 9.89
	1.83	+ 9.29	4.58	+ 9.17	9.15	+ 9.29	18.30	+ 9.29
	1.84	+ 8.70	4.60	+ 8.70	9.20	+ 8.70	18.40	+ 8.70
	1.85	+ 8.11	4.62	+8.20	9.25	+ 8.11	18.50	+ 8.11
	1.86	+ 7.53	4.65	+ 7.53	9.30	+ 7.53	18.60	+ 7.53
	1.87	+ 6.95	4.68	+ 6.84	9.35	+ 6.95	18.70	+ 6.95
	1.88	+ 6.38	4.70	+ 6.38	9.40	+ 6.38	18.80	+ 6.38
	1.89	+ 5.82	4.72	+ 5.93	9.45	+ 5.82	18.90	+ 5.82
Fast	1.90	+ 5.26	4.75	+ 5.26	9.50	+ 5.26	19.00	+ 5.26
	1.91	+ 4.71	4.78	+ 4.60	9.55	+ 4.71	19.10	+ 4.71
	1.92	+ 4.17	4.80	+ 4.17	9.60	+ 4.17	19.20	+ 4.17
	1.93	+ 3.63	4.82	+ 3.73	9.65	+ 3.63	19.30	+ 3.63
	1.94	+ 3.09	4.85	+ 3.09	9.70	+ 3.09	19.40	+ 3.09
	1.95	+ 2.56	4.88	+ 2.46	9.75	+ 2.56	19.50	+ 2.56
	1.96	+ 2.04	4.90	+ 2.04	9.80	+ 2.04	19.60	+ 2.04
	1.97	+ 1.52	4.92	+ 1.63	9.85	+ 1.52	19.70	+ 1.52
	1.98	+ 1.01	4.95	+ 1.01	9.90	+ 1.01	19.80	+ 1.01
	1.99	+ 0.50	4.98	+ 0.40	9.95	+ 0.50	19.90	+ 0.50
Correct	2.00	0.00	5.00	0.00	10.00	0.00	20.00	0.00
	2.01	−0.50	5.02	−0.40	10.05	−0.50	20.10	−0.50
	2.02	−0.99	5.05	−0.99	10.10	−0.99	20.20	−0.99
	2.03	−1.48	5.08	−1.57	10.15	−1.48	20.30	−1.48
	2.04	−1.96	5.10	−1.96	10.20	−1.96	20.40	−1.96
	2.05	−2.44	5.12	−2.34	10.15	−2.44	20.50	−2.44
	2.06	−2.91	5.15	−2.91	10.30	−2.91	20.60	−2.91
	2.07	−3.38	5.18	−3.47	10.35	−3.38	20.70	−3.38
	2.08	−3.85	5.20	−3.85	10.40	−3.85	20.80	−3.85
	2.09	−4.31	5.22	−4.21	10.45	−4.31	20.90	−4.31
	2.10	−4.76	5.25	−4.76	10.50	−4.76	21.00	−4.76
Slow	2.11	−5.21	5.28	−5.30	10.55	−5.21	21.10	−5.21
	2.12	−5.66	5.30	−5.66	10.60	−5.66	21.20	−5.66
	2.13	−6.10	5.32	−6.02	10.65	−6.10	21.30	−6.10
	2.14	−6.54	5.35	−6.54	10.70	−6.54	21.40	−6.54
	2.15	−6.98	5.38	−7.06	10.75	−6.98	21.50	−6.98
	2.16	−7.41	5.40	−7.41	10.80	−7.41	21.60	−7.41
	2.17	−7.83	5.42	−7.75	10.85	−7.83	21.70	−7.83
	2.18	−8.26	5.45	−8.26	10.90	−8.26	21.80	−8.26
	2.19	−8.68	5.48	−8.76	10.95	−8.68	21.90	−8.68
	2.20	−9.09	5.50	−9.09	11.00	−9.09	22.00	−9.09

The inlet of the meter is connected to the prover hose by means of a suitable connection. The connections and meter are then tested for leaks by opening the outlet valve on the prover connections, placing the palm of the hand over the meter outlet, and then closing the valve. If the siphon gauge shows a drop in pressure, it is an indication of a leak in the connection or in the meter. The leak can be located by means of soapsuds.

Attach the proper check cap on the meter outlet and pass enough air from the prover through the meter to bring the test hand, while on the up run, directly over a division or mark on the proving circle.

Fill the prover bell and carefully adjust the zero scale reading by means of the prover slide valve. Open the valve on the connection and pass a sufficient volume from the prover through the meter to cause the test hand to make one full revolution. Exercise care to insure that the test hand is stopped exactly over the mark from which it started at the beginning of the test. The reading on the prover scale is noted and from these data the proof is determined. If the meter is to be proof tested at the open rate, the procedure is the same as with the check rate test with the exception that the meter outlet is unrestricted. The maximum rate at which the prover delivers air through the hose and connections to the meter at the open-rate test depends upon the capacity of the meter, pressure in the prover, and size of connections from the interior of the prover to the meter.

Differential Test

The differential test of meters at a definite check rate is the supplementary test which is used as a final check to determine the absence of avoidable internal friction or binds in meters before final proof. For this purpose the differential, which is the difference in pressure between the inlet and outlet of the meter, is indicated in inches of water on a sensitive draft gauge.

At a very low rate of flow the differential is produced primarily by internal friction. In a properly assembled meter this internal friction depends upon the flexibility of the diaphragms, the relative tightness of the stuffing boxes, and to a certain extent, upon the clearance between the moving parts. In some cases where heavier diaphragms or tighter packing of the stuffing boxes are specified, a slightly higher differential will result. Consequently, for any particular size of meter, the differential limits will depend upon the specifications.

Any increase in differential resulting from binds, excessive friction in the stuffing boxes, or stiff diaphragm leather should be eliminated before final proof. This precaution is of basic importance because if internal friction is reduced by wear after a meter is placed in service, the proof may be affected.

At low rates of flow, the differential between meter inlet and outlet pressures may be about 0.10 inches of water.

American Meter Company, Inc.

Expressing Meter Accuracy

The comparison of the amount of registration of the meter, and the actual volume passed by the meter as shown by the decrease in volume in the prover, may be expressed in several ways.

The two general methods used might be called "percentage of error" and "percentage correction."

The percentage of error is more truly correct and significant in denoting the accuracy of the meter itself.

$$\text{Percentage of error} = \frac{100 \times (\text{meter reading} - \text{prover reading})}{\text{prover reading}}$$

The percentage of correction that should be used in adjusting a gas bill is figured as follows:

$$\text{Percentage correction} = \frac{100 \times (\text{meter reading} - \text{prover reading})}{\text{meter reading}}$$

All "percentage of error" or "correction" formulae as written give the correct algebraic sign for percentage which designates whether the meter is fast or slow. It should be noted that a plus percentage of correction should be subtracted from the meter reading to give corrected reading. A negative percentage correction should be added to the meter reading for corrected reading.

Bill adjustment =
Minus meter reading × percent correction.

The algebraic sign must be considered if we are to consider a fast meter as having a positive percent correction as has been the general practice when "percent correction" is used for "percent error."

The percentage of error is generally accepted as the correct method for expressing meter accuracy. Tables are available for correcting prover readings to "percentage error." Tables may be used for various proof bases.

It would seem more logical for the man proving the meter to record the prover reading.

If the accuracy of the meter is desired for meter study, the "percentage of error" method may be used.

If the correction is desired for bill adjustment, then the "percentage of correction" method may be used.

For convenience, the accompanying table has been prepared to show the percent of correction (or percent error in gas bill) versus percent error in meter.

If averages (although they mean very little) are desired, the total of the prover readings compared to the total meter readings gives a more accurate figure than the averages of percent error. This also eliminates algebraic signs which may be confusing in making the calculations. There is also less chance of error if prover readings are used as records.

The prover reading is the basic figure from which any method of calculation must start. It seems advisable to make this a permanent record.

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TABLE FOR CHANGING PERCENTAGE OF ERROR TO PERCENTAGE OF CORRECTION

FAST METERS

Per Cent Error In Meter	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
	Per Cent of Correction (Or Per Cent Error in Gas Bill)									
0	0 0	0 1	0 2	0 3	0 4	0 5	0 6	0 7	0 8	0 9
1	1 0	1 1	1 2	1 3	1 4	1 5	1 6	1 7	1 8	1 9
2	2 0	2 1	2 2	2 2	2 4	2 4	2 5	2 6	2 7	2 8
3	2 9	3 0	3 1	3 2	3 3	3 4	3 5	3 6	3 7	3 8
4	3 8	3 9	4 0	4 1	4 2	4 3	4 4	4 5	4 6	4 7
5	4 8	4 9	5 0	5 0	5 1	5 2	5 3	5 4	5 5	5 6
6	5 7	5 8	5 8	5 9	6 0	6 1	6 2	6 3	6 4	6 5
7	6 6	6 6	6 7	6 8	6 9	7 0	7 1	7 2	7 2	7 3
8	7 4	7 5	7 6	7 7	7 8	7 8	7 9	8 0	8 1	8 2
9	8 3	8 4	8 4	8 5	8 6	8 7	8 8	8 8	8 9	9 0
10	9 1	9 2	9 3	9 3	9 4	9 5	9 6	9 7	9 8	9 8
11	9 9	10 0	10 1	10 2	10 2	10 3	10 4	10 5	10 6	10 6
12	10 7	10 8	10 9	11 0	11 0	11 1	11 2	11 3	11 4	11 4
13	11 5	11 6	11 7	11 7	11 8	11 9	12 0	12 0	12 1	12 2
14	12 3	12 4	12 4	12 5	12 6	12 7	12 7	12 8	12 9	13 0
15	13 0	13 1	13 2	13 3	13 4	13 4	13 5	13 6	13 6	13 7
16	13 8	13 9	14 0	14 0	14 1	14 2	14 2	14 3	14 4	14 5
17	14 5	14 6	14 7	14 7	14 8	14 9	15 0	15 0	15 1	15 2
18	15 3	15 3	15 4	15 5	15 6	15 6	15 7	15 8	15 8	15 9
19	16 0	16 0	16 1	16 2	16 2	16 3	16 4	16 5	16 5	16 6
20	16 7	16 7	16 8	16 9	17 0	17 0	17 1	17 2	17 2	17 3
21	17 4	17 4	17 5	17 6	17 6	17 7	17 8	17 8	17 9	18 0
22	18 0	18 1	18 2	18 2	18 3	18 4	18 4	18 5	18 6	18 6
23	18 7	18 8	18 8	18 9	19 0	19 0	19 1	19 2	19 2	19 3
24	19 4	19 4	19 5	19 6	19 6	19 7	19 8	19 8	19 9	19 9
25	20 0	20 1	20 1	20 2	20 3	20 3	20 4	20 4	20 5	20 6

SLOW METERS

Per Cent Error In Meter	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
	Per Cent of Correction (Or Per Cent Error in Gas Bill)									
0	0 0	0 1	0 2	0 3	0 4	0 5	0 6	0 7	0 8	0 9
1	1 0	1 1	1 2	1 3	1 4	1 5	1 6	1 7	1 8	1 9
2	2 0	2 1	2 2	2 4	2 4	2 6	2 7	2 8	2 9	3 0
3	3 1	3 2	3 3	3 4	3 5	3 6	3 7	3 8	4 0	4 0
4	4 2	4 3	4 4	4 5	4 6	4 7	4 8	4 9	5 0	5 2
5	5 3	5 4	5 5	5 6	5 7	5 8	5 9	6 0	6 2	6 3
6	6 4	6 5	6 6	6 7	6 8	7 0	7 1	7 2	7 3	7 4
7	7 5	7 6	7 8	7 9	8 0	8 1	8 2	8 3	8 4	8 6
8	8 7	8 8	8 9	9 0	9 2	9 3	9 4	9 5	9 6	9 8
9	9 9	10 0	10 1	10 2	10 4	10 5	10 6	10 7	10 9	11 0
10	11 1	11 2	11 4	11 5	11 6	11 7	11 8	12 0	12 1	12 2
11	12 4	12 5	12 6	12 7	12 9	13 0	13 1	13 2	13 4	13 5
12	13 6	13 8	13 9	14 0	14 2	14 3	14 4	14 5	14 7	14 8
13	14 9	15 1	15 2	15 3	15 5	15 6	15 7	15 9	16 0	16 1
14	16 3	16 4	16 6	16 7	16 8	17 0	17 1	17 2	17 4	17 5
15	17 6	17 8	17 9	18 1	18 2	18 3	18 5	18 6	18 8	18 9
16	19 0	19 2	19 3	19 5	19 6	19 8	19 9	20 0	20 2	20 3
17	20 5	20 6	20 8	20 9	21 1	21 2	21 4	21 5	21 6	21 8
18	22 0	22 1	22 2	22 4	22 5	22 7	22 8	23 0	23 2	23 3
19	23 4	23 6	23 8	23 9	24 1	24 2	24 4	24 5	24 7	24 8
20	25 0	25 2	25 3	25 5	25 6	25 8	25 9	26 1	26 3	26 4
21	26 6	26 7	26 9	27 1	27 2	27 4	27 6	27 7	27 9	28 0
22	28 2	28 4	28 5	28 7	28 9	29 0	29 2	29 4	29 5	29 7
23	29 9	30 0	30 2	30 4	30 5	30 7	30 9	31 1	31 2	31 4
24	31 6	31 8	31 9	32 1	32 3	32 4	32 6	32 8	33 0	33 2
25	33 3	33 5	33 7	33 9	34 0	34 2	34 4	34 6	34 8	35 0

EXAMPLE: Assume a per cent error in meter which from test was 4.2% fast and a gas bill to be corrected of $17.00. It will be noted from the above table that with this per cent error in meter the gas bill is 4% too high. Then 4% of $17.00 is .04 x $17.00 or $0.68 too high.

REDUCTION OF BAROMETRIC READINGS

This table gives the corrections in inches of mercury to convert readings at various temperatures to readings at standard temperature.

	Observed reading of barometer in inches						
°F	24	25	26	27	28	29	30
0	+0.063	+0.065	+0.068	+0.070	+0.073	+0.075	+0.078
2	+0.058	+0.061	+0.063	+0.065	+0.068	+0.070	+0.073
4	+0.054	+0.056	+0.058	+0.061	+0.063	+0.065	+0.067
6	+0.049	+0.052	+0.054	+0.056	+0.058	+0.060	+0.062
8	+0.045	+0.047	+0.049	+0.051	+0.053	+0.054	+0.056
10	+0.011	+0.042	+0.044	+0.046	+0.047	+0.049	+0.051
12	+0.036	+0.038	+0.039	+0.041	+0.042	+0.042	+0.045
14	+0.032	+0.033	+0.035	+0.036	+0.037	+0.039	+0.040
16	+0.028	+0.029	+0.030	+0.031	+0.032	+0.033	+0.034
18	+0.023	+0.024	+0.025	+0.026	+0.027	+0.028	+0.029
20	+0.019	+0.020	+0.020	+0.021	+0.022	+0.023	+0.024
22	+0.014	+0.015	+0.016	+0.016	+0.017	+0.017	+0.018
24	+0.010	+0.011	+0.011	+0.011	+0.012	+0.012	+0.013
26	+0.006	+0.006	+0.006	+0.006	+0.007	+0.007	+0.007
28	+0.001	+0.001	+0.001	+0.002	+0.002	+0.002	+0.002
30	−0.003	−0.003	−0.003	−0.003	−0.003	−0.004	−0.004
32	−0.007	−0.008	−0.008	−0.008	−0.009	−0.009	−0.009
34	−0.012	−0.012	−0.013	−0.013	−0.014	−0.014	−0.015
36	−0.016	−0.017	−0.017	−0.018	−0.019	−0.019	−0.020
38	−0.020	−0.021	−0.022	−0.023	−0.024	−0.025	−0.026
40	−0.025	−0.026	−0.027	−0.028	−0.029	−0.030	−0.031
42	−0.029	−0.030	−0.032	−0.033	−0.034	−0.035	−0.036
44	−0.033	−0.035	−0.036	−0.038	−0.039	−0.040	−0.042
46	−0.038	−0.039	−0.041	−0.043	−0.044	−0.046	−0.047
48	−0.042	−0.044	−0.046	−0.047	−0.049	−0.051	−0.053
50	−0.046	−0.048	−0.050	−0.052	−0.054	−0.056	−0.058
52	−0.051	−0.053	−0.055	−0.057	−0.059	−0.061	−0.064
54	−0.055	−0.057	−0.060	−0.062	−0.064	−0.067	−0.069
56	−0.060	−0.062	−0.064	−0.067	−0.069	−0.072	−0.074
58	−0.064	−0.066	−0.069	−0.072	−0.074	−0.077	−0.080
60	−0.068	−0.071	−0.074	−0.077	−0.080	−0.082	−0.085
62	−0.073	−0.076	−0.079	−0.082	−0.085	−0.088	−0.091
64	−0.077	−0.080	−0.083	−0.086	−0.090	−0.093	−0.096
66	−0.081	−0.085	−0.088	−0.091	−0.095	−0.098	−0.101
68	−0.085	−0.089	−0.093	−0.096	−0.100	−0.103	−0.107
70	−0.090	−0.094	−0.097	−0.101	−0.105	−0.109	−0.112
72	−0.094	−0.098	−0.102	−0.106	−0.110	−0.114	−0.118
74	−0.098	−0.103	−0.107	−0.111	−0.115	−0.119	−0.123
76	−0.103	−0.107	−0.111	−0.116	−0.120	−0.124	−0.128
78	−0.107	−0.112	−0.116	−0.120	−0.125	−0.129	−0.341
80	−0.111	−0.116	−0.121	−0.125	−0.130	−0.135	−0.139
82	−0.116	−0.121	−0.125	−0.130	−0.135	−0.140	−0.145
84	−0.120	−0.125	−0.130	−0.135	−0.140	−0.145	−0.150
86	−0.124	−0.130	−0.135	−0.140	−0.145	−0.150	−0.155
88	−0.129	−0.134	−0.139	−0.145	−0.150	−0.155	−0.161
90	−0.133	−0.138	−0.144	−0.150	−0.155	−0.161	−0.166
92	−0.137	−0.143	−0.149	−0.154	−0.160	−0.166	−0.172
94	−0.142	−0.147	−0.153	−0.159	−0.165	−0.171	−0.177
96	−0.146	−0.152	−0.158	−0.164	−0.170	−0.176	−0.182
98	−0.150	−0.156	−0.163	−0.169	−0.175	−0.181	−0.188
100	−0.154	−0.161	−0.167	−0.174	−0.180	−0.187	−0.193

From Table 44 of Smithsonian Meteorological Tables, 1939.
Example:

Observed height of barometer	= 29.502
Attached thermometer, 68 degrees F. Reduction for temperature	= 0.105
Barometer reading corrected for temperature	= 29.397

ATMOSPHERIC PRESSURE

This table is compiled from elevations and normal atmospheric pressures at United States Weather Bureau stations.

Elevation in feet	Inches mercury	Pounds absolute	Elevation in feet	Inches mercury	Pounds absolute
0	30.00	14.73	2000	27.90	13.70
100	29.89	14.68	2500	27.39	13.45
200	29.78	14.63	3000	26.90	13.21
300	29.67	14.57	3500	26.41	12.97
400	29.56	14.52	4000	25.93	12.74
500	29.45	14.46	4500	25.46	12.50
600	29.34	14.41	5000	25.00	12.28
800	29.13	14.31	5500	24.54	12.05
1000	28.93	14.21	6000	24.10	11.84
1500	28.41	13.95	6500	23.67	11.63

ALTITUDE AND ATMOSPHERIC PRESSURE

This table from the United States Weather Bureau gives altitudes and average atmospheric pressures.

Location	Elevation in feet above sea level	Average atmospheric pressure pounds	Location	Elevation in feet above sea level	Average atmospheric pressure pounds
Abilene, Tex.	1738	13.85	Hartford, Conn.	159	14.66
Albany, N. Y.	97	14.70	Helena, Mont.	4110	12.67
Amarillo, Tex.	3676	12.90	Houston, Tex.	138	14.68
Asheville, N. C.	2253	13.62	Indianapolis, Ind.	822	41.32
Atlanta, Ga.	1173	14.16	Kansas City. Mo.	963	14.23
Atlantic City, N. J.	52	14.72	Keokuk, Iowa	614	14.42
Austin, Tex.	605	14.43	Knoxville, Tenn.	995	14.25
Baker, Ore.	3471	13.01	Lander, Wyo.	5372	12.10
Baltimore, Md.	123	14.69	Lincoln, Neb.	1189	14.11
Binghamton, N. Y.	871	14.29	Los Angeles, Cal.	338	14.55
Birmingham, Ala.	700	14.39	Louisville, Ky.	525	14.48
Bismarck, N. Dak.	1674	13.84	Madison, Wis.	974	14.23
Boise, Idaho	2739	13.35	Memphis, Tenn.	399	14.55
Boston, Mass.	125	14.67	Miami, Fla.	25	14.74
Brownsville, Tex.	57	14.69	Milwaukee, Wis.	681	14.38
Buffalo, N. Y.	767	14.33	Minneapolis, Minn.	918	14.23
Burlington, Vt.	403	15.51	Montgomery, Ala.	223	14.65
Cairo, Ill.	358	14.57	Nashville, Tenn.	546	14.48
Charleston, S. C.	48	14.74	New Orleans, La.	53	14.73
Charlotte, N. C.	779	14.36	New York, N. Y.	314	14.58
Chattanooga, Tenn.	762	14.37	North Platte, Neb.	2821	13.29
Cheyenne, Wyo.	6088	11.79	Oklahoma City, Okla.	1214	14.11
Chicago, Ill.	673	14.39	Omaha, Neb.	1105	14.16
Cincinnati, Ohio	627	14.43	Parkesburg, W. Va.	637	14.45
Cleveland, Ohio	762	14.34	Philadelphia, Pa.	114	14.70
Columbia, N. C.	784	14.34	Pittsburgh, Pa.	842	14.31
Columbus, Ohio	822	14.33	Pocatello, Idaho	4477	12.52
Concord, N. H.	289	14.57	Pueblo, Colo.	4685	12.42
Corpus Christi, Tex.	20	14.72	Rapid City, S. Dak.	3259	13.06
Dallas, Tex.	512	14.47	Reno, Neb.	4532	12.51
Dayton, Ohio	899	14.29	Rochester, N. Y.	523	14.46
Del Rio, Tex.	944	14.22	Roswell, N. Mex.	3566	12.95
Denver, Colo.	5292	12.14	Sacramento, Cal.	69	14.69
Des Moines, Iowa	861	14.29	St. Louis, Mo.	568	14.45
Detroit, Mich.	730	14.36	St. Paul, Minn.	837	14.28
Dodge City, Kan.	2509	13.46	Salt Lake City, Utah	4360	12.50
Dubuque, Iowa	700	14.37	San Antonio, Tex.	693	14.38
Duluth, Minn.	1133	14.12	San Diego, Cal.	87	14.68
Elkins, W. Va.	1947	13.77	San Francisco, Cal.	155	14.66
El Paso, Tex.	3778	12.86	Santa Fe, N. Mex.	7013	11.44
Erie, Pa.	714	14.37	Seattle, Wash.	125	14.69
Evansville, Ind.	431	14.53	Shreveport, La.	249	14.62
Fort Smith, Ark.	457	14.50	Spokane, Wash.	1929	13.74
Fort Wayne, Ind.	856	14.29	Syracuse, N. Y.	597	14.43
Fort Worth, Tex.	670	14.39	Toledo, Ohio	628	14.42
Grand Rapids, Mich.	707	14.37	Washington, D. C.	112	14.70
Harrisburg, Pa.	374	14.55	Yuma, Ariz.	141	14.61

MERCURY VACUUM — ABSOLUTE PRESSURE

Based on atmospheric pressure of 14.4 pounds and mercury at 32 degrees F.

Inches mercury vacuum	Inches mercury absolute	Pounds per square inch absolute	Inches mercury vacuum	Inches mercury absolute	Pounds per square inch absolute
1	28.32	13.91	16	13.32	6.54
2	27.32	13.42	17	12.32	6.05
3	26.32	12.93	18	11.32	5.56
4	25.32	12.44	19	10.32	5.07
5	24.32	11.94	20	9.32	4.58
6	23.32	11.45	21	8.32	4.09
7	22.32	10.96	22	7.32	3.59
8	21.32	10.47	23	6.32	3.10
9	0.32	9.98	24	5.32	2.61
10	19.32	9.49	25	4.32	2.12
11	18.32	9.00	26	3.32	1.63
12	17.32	8.51	27	2.32	1.14
13	16.32	8.01	28	1.32	0.65
14	15.32	7.52	29	0.32	0.16
15	14.32	7.03	30	....	....

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Meter Sizing and Selection

Selection of meters for domestic and small commercial loads should be made with regard to several factors:

1. **Meter Capacity.** Meter or meters should be selected to deliver either a design load or a rated connected load. Meter capacities in the tables accompanying this section should be used when metering at pressures up to 7-in. w. c. (4 oz.). When metering is to be done at higher pressures, manufacturers' recommendations or data developed by individual company measurement or engineering departments should be followed.
2. **Space requirements.** Occasionally, available space will be a factor in selecting the type of meter or meters to be used.
3. **Nature of customer's use.**
4. **Available meter stocks.**
5. **Operating pressure.**

In selecting any meter by use of the capacities shown in the accompanying tables (or other tables or curves developed by individual companies), consideration must be given to the type of load. If load remains at or near peak load, a substantial part of the operating time, and rated capacity of the meter is about the same as the load, the next larger meter should be selected.

Likewise, while it is important that a meter of sufficient capacity be installed, it is also important from the standpoint of economics not to use a larger, more expensive meter than is necessary.

Selection of Meter Location

Meter location and installation varies considerably with companies and localities. In general, a good meter location fulfills the following requirements:

1. Ease of reading and inspection.
2. Accessibility for turn-on, shut-off, change, or removal.
3. Protection against moisture, corrosive substances, extreme high or low temperatures, electric sparks, and accidental damage.
4. Adequate ventilation.
5. Minimum length of exposed piping.
6. Does not detract excessively from appearance of customer's property.

Outside set meters should be located, in order of preference, on the inactive side of the house, or in front of the house, or at the rear of the house.

Where two or more meters are to be located on a particular premise, they should be located as close together as practical. If meter is to be located in an alley or driveway, it should be at such a height that it is free of the hazards of traffic. Meters can also be elevated on the side of buildings, or a permanent guard made of pipe can be placed around the meter. Such practices vary according to locality and necessity.

Table of Maximum Appliance Consumption

Appliance	Btu's per hour
Domestic ranges	
Top burners	9–10,000
Giant burners	12,000
Ovens	16–18,000
Refrigerators	5,000
Water heaters	
Small	20,000
Medium	30–35,000
Large	55,000
Space heaters	
Per single candle	2,000
Per double candle	4,000
Incinerators	
Constant burning type	2,000
2 Bushel	15,000
4 Bushel (Commercial)	25,000
Laundry dryers	
Rotary type	20,000
Cabinet type	35,000
Circulating heaters	Use rated input
Central heating plants	
Gas designed	Use rated input
Conversion	Use calculated input

NOTE: This table furnishes the ratings of most of the appliances that have been sold in the last few years. Where appliances carry badged ratings, such ratings should be used. For older appliances, best estimate of gas requirements will be sufficiently close for this purpose.

Estimating Demand Per Hour

In sizing meters, an estimate of total probable demands is considered a reliable method. The Table of Maximum Appliance Consumption is of help in arriving at this estimate. Where appliances carry badged ratings, such ratings should be used. The table should be revised for each locality to include kinds and types of appliances generally used. Where automatic equipment is used, 100% of the ratings should be used in estimating, and for all other appliances a 70% factor may be used.

Estimated maximum demand per hour can be determined as follows:

$$\text{Maximum Demand in cu ft per hr} = \frac{0.70\,A + 1.00\,B}{C}$$

Where:

A = Btu rating per hr of non-automatic appliances
B = Btu rating per hr of all automatic appliances
C = Btu content of gas being distributed at meter

Following is an example of the application of the table in arriving at an estimate of demand per hour, assuming 1000 Btu per cu ft natural gas:

Appliance	Rating Btu per hour	Total demand Btu per hour
Range (4 burner)	62,500	
Space heater	20,000	
Incinerator	15,000	
	97,500 at 70%	68,250
Instantaneous		
Water heater	150,000	
Hot water boiler	180,000	
	330,000 at 100%	330,000
		398,250

The total demand in cu ft per hour is $\frac{398{,}250}{1000}$ or 398 cu ft per hr. As this is almost 400 cu ft per hr, a meter of that capacity may be chosen. If there is a possibility that the load might operate at the total demand for long periods, a slightly larger meter, e.g., of 415 or 425 cu ft per hr rated capacity, may be installed.

Determining Type of Meter to Install

Many utilities use both tincase and hardcase (iron or aluminum) meters in their systems.

Hardcase meters are used wherever meters are installed out-of-doors and in any case where tincase meters should not be used. Many companies are standardizing on hardcase meters due to ease of repair, less repairman training required, etc., especially in areas where most new construction is basementless and meter sets are being made outside.

Tincase meters are used for installations where the meter can be placed inside, with certain exceptions:

1. In areas subject to frequent flooding.
2. In areas where existing installations are predominately hardcase meters.
3. Where pressure in service line exceeds 5 psig (or a predetermined pressure limit set by company practice.)

Diversity Factors

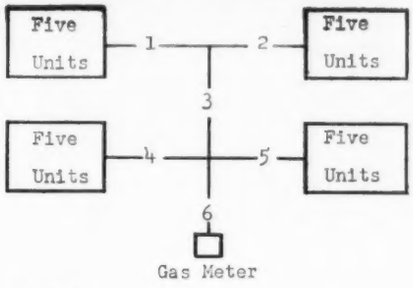
The *diversity load factor* is used in determining the correct pipe size to use in multi-family dwellings served from a single meter, and in determining the correct size of meter to use for such service.

This factor is commonly considered a percentage of the total connected load in use at any one time, and is dependent upon the number and types of gas appliances installed.

The diversity factor shown in the accompanying graph, representing one company's experience, is based on a minimum average daily temperature of 20 F. The diversity factor can be used when the number of dwelling units is known. Maximum gas consumption in cu ft per hr that must be provided is equal to the product of the total connected load in cu ft per hr multiplied by the diversity factor found on the graph.

Example: The following illustrates the use of the diversity factor on the design of a piping installation and in sizing the meter.

Assume that four buildings each having five dwelling units are to be built and gas piping is to be installed as shown in the plan; each unit has a total connected load of 200 cu ft per hr. Maximum gas consumption for which each line should be designed and size of meter are determined as follows:

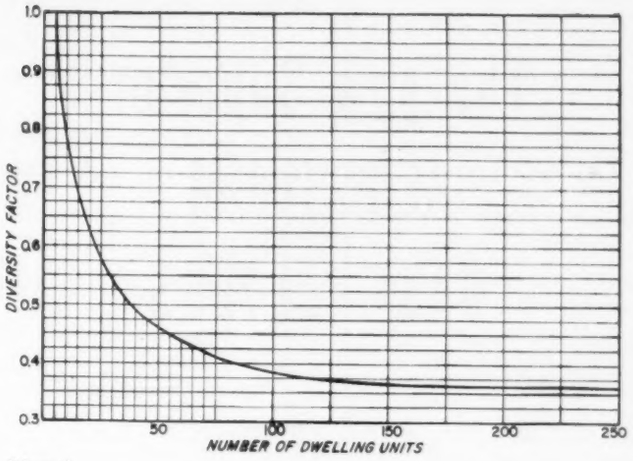


Lines 1, 2, 4 and 5

A. Total connected load = 5 x 200 = 1000 cu ft per hr
B. Diversity factor for 5 units (see graph) = 1.0 or 100%
C. Maximum gas consumption to be provided:
1000 × 1.0 = 1000 cu ft per hr

Line 3:

A. Total connected load = 2 × 1000 = 2000 cu ft per hr
B. Diversity factor for 10 units (see graph) = 0.78 or 78%
C. Maximum gas consumption to be provided:
2000 × 0.78 = 1560 cu ft per hr



Line 6:

A. Total connected load = 4 × 1000 = 4000 cu ft per hr
B. Diversity factor for 20 units (see graph) = 0.63 or 63%
C. Maximum gas consumption to be provided:
4000 × 0.63 = 2520 cu ft per hr

Meter Sizing

Meter selected should have sufficient capacity to handle 2520 cu ft per hr at the predetermined pressure drop.

Tincase Meter Data

Mfr: American

Model or size	Rated capacity in cu ft per hr ½" w.c.	2" w.c.
5-B	150	300
10-B	300	600
20-B	450	900
30-B	600	1,200
60-B	1300	2,600
100-B	1800	3,600
200-B	3200	6,400
5-M	210	420
5-M	250	500
5-M	300	600
10-M	425	850
30-M	900	1,800
60-M	1700	3,400
20-A	600	1,200
150-A	3400	6,800
6-C	600	1,200
11-C	1100	2,200
25-C	2500	5,000
40-C	4000	8,000
60-C	6000	12,000
W-75	75	
W-175	175	360
W-210	210	425
W-250	250	510
W-300	300	615

Mfr: Rockwell

Model or size	Rated capacity in cu ft per hr ½" w.c.	2" w.c.
5-150	150	300
5-200	200	400
5-250	250	500
5-300	300	600
10-300	300	600
10-425	425	850
10-500	500	1,000

Mfr: Superior

Model or size	Rated capacity in cu ft per hr ½" w.c.	2" w.c.
5-A	210	420
5-AA	250	500
5-AA	300	600
10-A	400	800
20-A	600	1,200
30-A	900	1,800
60-A	1500	3,000
5-B	150	300
10-B	300	600
20-B	450	900
30-B	600	1,200
60-B	1300	2,600
6-C	600	1,200
11-C	1100	2,200
25-C	2500	5,000
40-C	4000	8,000
60-C	6000	12,000
75-C	7500	15,000
2-T	80	
2-T	100	
2-T	140	
5-T	150	300
5-T	210	420
5-T	250	500
5-T	300	600
10-T	300	600
10-T	400	800

Hardcase Meter Data

Mfr: Sprague

Model or size	Maximum working pressure (psi)	Low pressure capacities, cfh ½" w.c.	2" w.c.
175(1-A)	5	175	350
175C(1-C)	5	175	350
240	5	240	480
305(2)	5	305	610
400(3)	5	400	800
675(4)	15	675	1,450
5	5	856	1,710
1000(5-A)	5	1000	2,000
7	N.A.	5000	10,000
20	N.A.	16,000	32,000

Mfr: American

Model or size	Maximum working pressure (psi)	Low pressure capacities, cfh ½" w.c.	2" w.c.
5-B	5	175	370
AL-175	5	175	370
5-B-225	5	225	450
AL-250	5	250	500
10-B	5–100	250	570
20-B	10	350	700
25-B	10–250	400	900
AL-425	10	425	900
30-B	15	550	1,100
35-B	15–100	650	1,500
AL-800	20	800	1,700
60-B	20–100	950	2,000
80-B	20–250	1200	2,500
250-B	75–250	3000	6,000
500-B	75–250	4800	10,000

Mfr: Rockwell

Mode or size	Maximum working pressure (psi)	Low pressure capacities, cfh ½" w.c.	2" w.c.
150 (00*)	5	150	300
175 (0*)	5–50	175	350
250	5–10	250	500
1*	5	275	550
310	5–10	310	620
2*	10	415	830
415	10	415	830
750	20	750	1,600
1600 (800*)	100	800	1,600
2½	20–1000	950	2,000
3	20–500	1200	2,500
3000	100	1450	3,000
4	20–500	2250	5,000
5000	100	2250	5,000
4½	75	3500	7,000
5	50	5000	10,000
10,000	100	5000	10,000

*No longer in production

Mfr: Superior

Model or size	Maximum working pressure (psi)	Low pressure capacities, cfh ½" w.c.	2" w.c.
175	5	180	360
250	5	255	510
340	5	350	700

The new Superior ALUMINUM CASE METERS

. . . in 175 cfh, 250 cfh, and 340 cfh sizes to meet most domestic requirements.

The *newest* meter on the market . . . a unique combination of time-tested advances in domestic meter construction. Outstanding long life and accuracy are built into this meter . . . from the double-adjustable tangent to the cast-in bottom bearings. Service and maintenance are remarkably easy, too. All internal parts are assembled to the valve table and can be removed as a unit for rapid inspection. Index and index box can be removed independently without touching the meter cover or any other parts; this feature permits on-the-site replacement of either part. New index stuffing box construction is extremely simple . . . practically eliminates leakage in the field.

Get full details. Send for bulletin 1150H.

Look at these advanced design features:

1. Simple, horizontal seam . . . eliminates leakage . . . easier maintenance.
2. Easily accessible table . . . just remove the screws holding top.
3. Meter top removable without taking off index box.
4. Valve seat readily accessible for grinding when top is removed.
5. New carriage bearing construction permits maximum support of diaphragm throughout entire stroke.
6. Seam gasket stays resilient . . . cork and Buna-N composition.
7. Valve table lifts out with entire mechanism.
8. Heavy-duty, sintered bronze bearing oil-impregnated for life.
9. Flag arrangement gives arm smoother operation and longer life.
10. Gall-proof and corrosion resistant steel spuds are die-cast in meter body.
11. Cupped handling lids permit easy and safe carrying.
12. Handy access for tangent adjustment and calibration.
13. Broad base for solid stacking . . . designed for conveyorized handling.
14. Index and index box can be replaced on-the-site without touching any other parts.

BRANCH OFFICES

Atlanta • Brooklyn • Chicago • Columbus • Dallas • Denver • Los Angeles • Louisville • North Kansas City, Mo.
Philadelphia Area (Bala-Cynwyd) • Portland

IN CANADA

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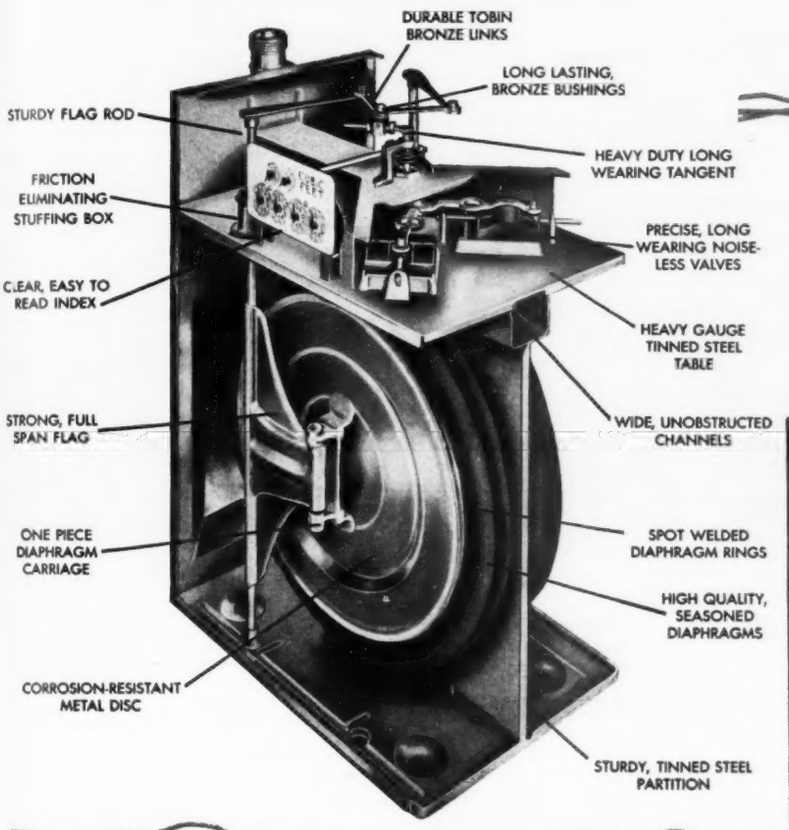
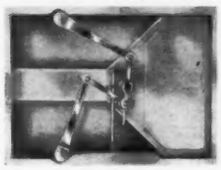
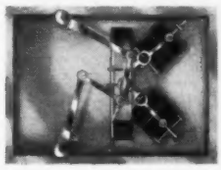
SUPERIOR GAS METERS

Tinned Steel Case Meters


DURABLE TOBIN BRONZE LINKS
LONG LASTING, BRONZE BUSHINGS
STURDY FLAG ROD
HEAVY DUTY LONG WEARING TANGENT
FRICTION ELIMINATING STUFFING BOX
PRECISE, LONG WEARING NOISE-LESS VALVES
CLEAR, EASY TO READ INDEX
HEAVY GAUGE TINNED STEEL TABLE
STRONG, FULL SPAN FLAG
WIDE, UNOBSTRUCTED CHANNELS
ONE PIECE DIAPHRAGM CARRIAGE
SPOT WELDED DIAPHRAGM RINGS
HIGH QUALITY, SEASONED DIAPHRAGMS
CORROSION-RESISTANT METAL DISC
STURDY, TINNED STEEL PARTITION



CLOSED TOP CONSTRUCTION: Tinned steelplate mounting stand protects valves and working parts from gums, dirt and other foreign matter commonly found in certain gas conditions.



OPEN TOP CONSTRUCTION: Excellent for clean gas conditions. Valves and moving parts immediately accessible under casing cover. Permits easier maintenance, faster servicing, quicker "O.K.'s."

METER SPECIFICATIONS

	Size	Rated Capacity in Cu. Ft. Per Hr.	Pipe Size–Inches	Net Weight Pounds	Width Center to Center of Pipe–In.	Height to Top of Pipes Inches	Proving Head–Feet	Revolutions Per Foot
TYPE "A"	5	210	½	15½	11⅜	16⅝	2	6
	5	250	½	15½	11⅜	16⅝	2	6
	5	300	¾	15½	11⅜	16⅝	2	6
	10	400	¾	23½	13⅜	18½	5	3⅗
	20	600	1	40½	16⅛	22	5	2
	30	900	1¼	47½	18¼	26¼	5	1⅗
	60	1500	1½	118	25¼	33⅛	20	½
TYPE "B"	5	150	½	15½	11⅜	16⅝	2	6
	10	300	¾	23½	13⅜	18½	5	3⅗
	20	450	1	34	16⅛	22	5	2⅕
	30	600	1¼	47½	18¼	26¼	5	1⅗
	60	1300	1½	117	24	31⅜	10	⅗
TYPE "C"	6	600	1¼	35	14⅜	19¾	10	1⅘
	11	1100	2	68	19⅜	27¾	10	⅘
	25	2500	2½	156	25⅜	34	20	7⁄20
	40	4000	3	215	29¼	38½	50	⅕
	60	6000	4	400	36	45¼	100	1⁄10
	75	7500	4	400	36	45¼	100	1⁄10
TYPE "T"	2	80	½	8.3	7¾	12⅝	1	20
	2	100	½	8.3	7¾	12⅝	1	20
	2	140	½	8.3	7¾	12⅝	1	20
	5	150	½	15½	11⅜	16⅝	2	6
	5	210	½	15½	11⅜	16⅝	2	6
	5	250	½	15½	11⅜	16⅝	2	6
	5	300	¾	15½	11⅜	16⅝	2	6
	10	300	¾	23½	13⅜	18½	5	3⅗
	10	425	¾	23½	13⅜	18½	5	3⅗

Superior manufactures a complete line of Tinned-Steel case gas meters from 80 to 7500 cfh. designed to enable meter supervisors to meet the specific requirements of their area. Widely-used, slow-operating diaphragm Type B meters . . . higher capacity Type A meters . . . heavy duty, large capacity Type C meters, and open-top Type T meters for clean gas conditions. All are designed and manufactured for dependable sustained accuracy, easier repairs and lower maintenance costs.

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NEPTUNE METER COMPANY
167 – 41st Street, Brooklyn 32, N.Y.

High Pressure Measurement With PD Meters

Gas meters always measure the gas at line pressure. It is not always practicable to reduce the pressure and measure the gas at low pressure. In many instances it would be necessary to compress the gas again to transmit it to the point of consumption.

Meters for high pressure service have the same measuring mechanism as those employed for low pressure. The only difference is in the strength of the case.

If the line pressure does not remain constant, it is necessary to equip the meter with a recording volume and pressure gage in order to arrive at the correct base or selling pressure. The correct volume is computed from the gage chart and a pressure table.

If the line pressure remains constant, a pressure and volume gage is not necessary. The correct pressure factor may be taken from the table and applied directly to the meter reading.

The generally accepted average atmospheric pressure is 14.4 psi. Gage pressure is the difference between the absolute pressure and the atmospheric pressure, viz., the absolute pressure equals the atmospheric pressure plus gage pressure. Absolute pressure must be used in all gas calculations involving the gas laws.

The method of converting volume measured at high pressure to volume at a base or selling pressure is as follows:

$$Q = q \times K_{pb}$$

Where:

Q = quantity in cu ft at base pressure

q = cu ft registered by meter, index reading

K_{pb} = pressure base factor read from table below

Example:

Given: Meter index reading = 215,512
Atmospheric pressure = 14.4 psi
Base pressure = 4 oz
Gage pressure = 45 psi

Then: in the table under "Base pressure 4 oz" read the constant for 45 psig, which is 4.055.

The volume measured at sales pressure then:

$Q = 4.055 \times 215{,}512$
$= 873{,}901$ cu ft

If the pressure varies, it is necessary to employ a recording volume and pressure gage. An average pressure for the volume measured is calculated from the gage chart. This average pressure is then interpolated in table of pressure factors and the calculations from this point are identical to those employed for a constant pressure.

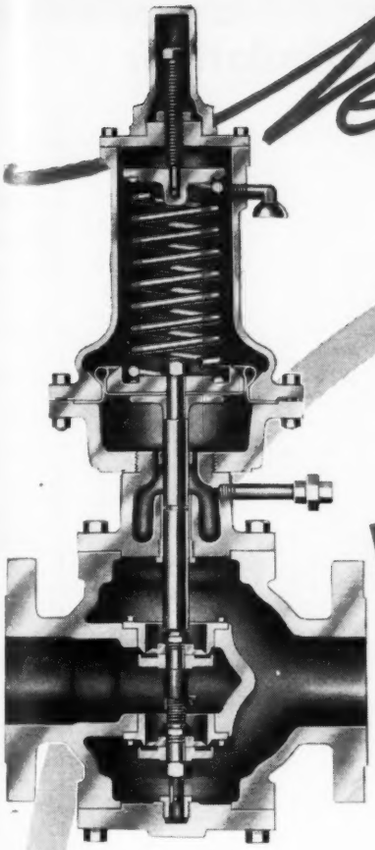
Pressure Factors for High Pressure Measurement

Gauge pressure pounds	Base pressure, pounds absolute 14.65 (4 oz.)	14.9 (8 oz.)	15.025 (10 oz.)	16.4 (2 lb.)	Gauge pressure pounds	Base pressure, pounds absolute 14.65 (4 oz.)	14.9 (8 oz.)	15.025 (10 oz.)	16.4 (2 lb.)
0	0.983	0.966	0.958	0.878	38	3.577	3.517	3.488	3.195
1	1.051	1.034	1.025	0.939	39	3.645	3.584	3.554	3.256
2	1.119	1.101	1.092	1.000	40	3.713	3.651	3.621	3.317
3	1.188	1.168	1.158	1.061	41	3.782	3.718	3.687	3.378
4	1.256	1.235	1.225	1.122	42	3.849	3.785	3.754	3.439
5	1.324	1.302	1.291	1.183	43	3.918	3.852	3.820	3.500
6	1.392	1.369	1.358	1.244	44	3.986	3.919	3.887	3.561
7	1.461	1.436	1.424	1.305	45	4.055	3.987	3.953	3.622
8	1.529	1.503	1.491	1.366	46	4.123	4.054	4.020	3.683
9	1.597	1.570	1.557	1.427	47	4.191	4.121	4.087	3.744
10	1.666	1.638	1.624	1.488	48	4.259	4.188	4.153	3.805
11	1.734	1.705	1.691	1.549	49	4.328	4.255	4.220	3.866
12	1.802	1.772	1.757	1.610	50	4.396	4.322	4.286	3.927
13	1.870	1.839	1.824	1.671	51	4.464	4.389	4.353	3.988
14	1.939	1.906	1.890	1.732	52	4.352	4.456	4.419	4.049
15	2.007	1.973	1.957	1.793	53	4.601	4.523	4.486	4.110
16	2.075	2.040	2.023	1.854	54	4.669	4.591	4.552	4.171
17	2.143	2.107	2.090	1.915	55	4.737	4.658	4.619	4.232
18	2.212	2.174	2.156	1.976	56	4.805	4.725	4.686	4.293
19	2.280	2.242	2.223	2.037	57	4.874	4.792	4.752	4.354
20	2.348	2.309	2.290	2.098	58	4.942	4.859	4.819	4.415
21	2.416	2.376	2.356	2.159	59	5.010	4.926	4.885	4.476
22	2.485	2.443	2.423	2.220	60	5.078	4.993	4.952	4.537
23	2.553	2.510	2.489	2.280	61	5.147	5.060	5.018	4.598
24	2.621	2.577	2.556	2.341	62	5.215	5.128	5.085	4.659
25	2.689	2.644	2.622	2.402	63	5.283	5.195	5.151	4.720
26	2.758	2.711	2.689	2.463	64	5.352	5.262	5.218	4.780
27	2.826	2.779	2.755	2.524	65	5.420	5.329	5.285	4.841
28	2.894	2.846	2.822	2.585	66	5.488	5.396	5.351	4.902
29	2.962	2.913	2.889	2.646	67	5.556	5.463	5.418	4.963
30	3.031	2.980	2.955	2.707	68	5.625	5.530	5.484	5.024
31	3.099	3.047	3.022	2.768	69	5.693	5.597	5.551	5.085
32	3.167	3.114	3.088	2.829	70	5.761	5.664	5.617	5.146
33	3.235	3.181	3.155	2.890	71	5.829	5.732	5.684	5.207
34	3.304	3.248	3.221	2.951	72	5.898	5.799	5.750	5.268
35	3.372	3.315	3.288	3.012	73	5.966	5.866	5.817	5.329
36	3.440	3.383	3.354	3.073	74	6.034	5.933	5.884	5.390
37	3.509	3.450	3.421	3.134	75	6.102	6.000	5.950	5.451

New in principle!

CHAPLIN-FULTON

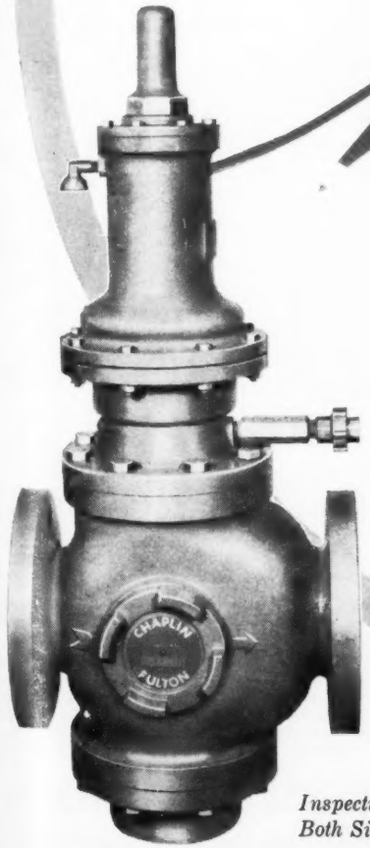
MODEL 441-57S GAS REGULATOR



SIZE: 2"—3"—4"—6"
125 lb. iron—W. P. 175 psi
250 lb. ductile—W. P. 400 psi
Series 30 steel—W. P. 720 psi

Model 57-S, a simple spring loaded regulator, operates on a new diaphragm principle which will control accurately until the regulator is wide open. The outlet pressure "fall-off," typical of spring regulators, is eliminated—not by an uncontrolled velocity effect—but by a diaphragm which changes its size as the valve moves to give straight line control. For pounds-to-pounds service,—controlled pressures to 75 psi with same assembly.

New in design!



Inspection Plates Both Sides.

Also, a new body design—441—with gas exit areas greatly enlarged to prevent turbulence and increase capacity.
And to help in your visual inspection program—side inspection plates on *both* sides of the body have been included. Screwed-on with O-ring seal, they can be quickly removed and replaced—no gasket problem. Standard face-to-face dimensions now make the 441 interchangeable with other regulators.

ACCURATE CP MFG CO DEPENDABLE

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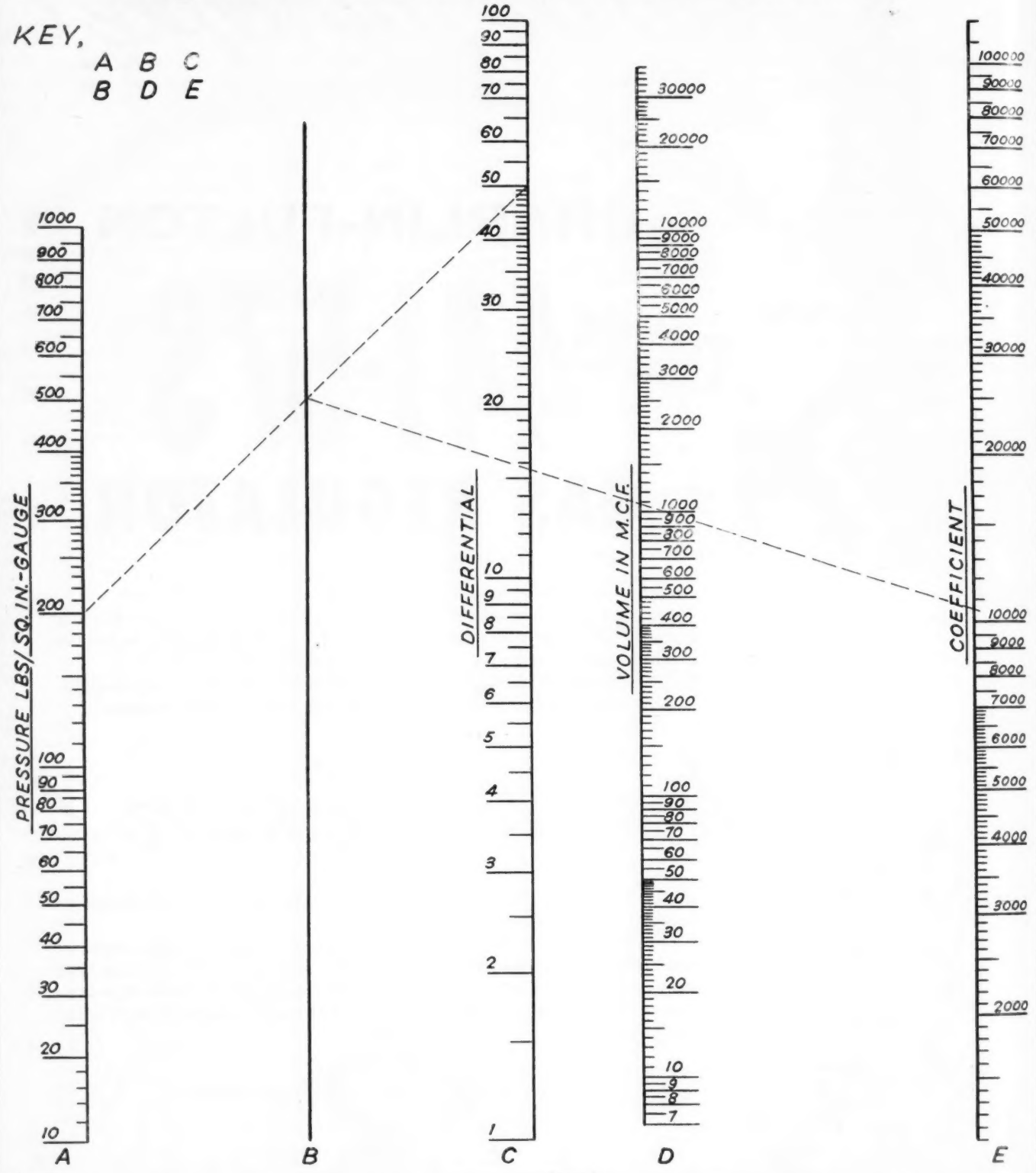
Alignment Chart for Orifice Meter Calculations



Example:

Given: Flange tap connections; pressure base 8 oz., 14.4 lb.; pipe size, 12-in. std.; orifice dia., 6¼-in.; coefficient, 108.20 × 0.9664 equal 10456.4; pressure, 200 lb. ga.; and differential, 50 in.

Required: Volume in Mcf per hour at 8 oz., 14.4 lb.

Solution: Dotted lines on chart for this example show volume equal 1090 Mcf.

Factors to change from pressure base of 14.4 psia to some other contract pressure base

New base	psia	factor	New base	psia	factor
14.4	= 14.400	= 1.0000	14.7	= 14.700	= .9796
14.4 + 4 oz	= 14.650	= .9829	14.7 + 2 oz	= 14.825	= .9713
30-in. Hg abs	= 14.730	= .9776	14.7 + 4 oz	= 14.950	= .9632
14.4 + 8 oz	= 14.900	= .9664	14.7 + 10 oz	= 15.325	= .9396
14.4 + 10 oz	= 15.025	= .9584	14.7 + 2 lb	= 16.700	= .8623

Example:

Given: Pipe tap connections; pressure base, 14.4 lb.; pipe size, 4-in. std.; pressure, 250 lb. ga.; desired differential, 32 in., and desired volume, 1000 Mcf per day.

Required: Proper orifice size.

Solution: Draw a line from 250 lb. on scale A to 32 in. on scale C. From the intersection of this line on scale B, draw another line through 1000 Mcf on scale D until it crosses the coefficient scale E. Now divide 10800 by 24 hours and obtain 450, the hourly coefficient. From the table of Basic Orifice Coefficients, the proper orifice diameter will be 1¼ in.

NOTE: This chart to be used in conjunction with Sheet 2 containing basic orifice coefficients—pipe taps and flange taps. Key to chart is in upper left corner.

—Chart by W. D. Parkes, United Gas Pipe Line Company.

Alignment Chart for Orifice Meter Calculations

Basic orifice coefficients — Pipe Taps

Base temperature = 60°F. Flowing temperature = 60°F.
Base pressure = 14.4 lb. per sq. in. Specific gravity = 0.60

Orifice diameter in.	Pipe sizes—nominal and actual diameters				
	4-in. std. 4.026-in.	6-in. std. 6.065-in.	8-in. std. 8.071-in.	10-in. std. 10.136-in.	12-in. std. 12.090-in.
½	68.5	67.8			
¾	156.4	154.1			
1	282.6	276.7	274.1	272.3	
1¼	451.3	436.6	431.3	428.2	
1½	670.0	635.7	625.6	620.1	616.7
1¾	951.3	877.0	858.0	848.9	843.4
2	1314.0	1165.0	1130.3	1115.3	1106.9
2¼	1784.5	1506.1	1444.6	1420.4	1407.7
2½	2396.0	1909.0	1804.6	1765.4	1746.7
2¾		2385.4	2213.9	2152.7	2124.7
3		2949.9	2678.6	2584.5	2543.4
3¼		3621.3	3205.2	3063.7	3004.2
3½		4420.8	3802.1	3594.4	3509.2
3¾		5375.7	4479.4	4181.0	4061.0
4			5249.6	4829.1	4662.2
4¼			6126.6	5545.4	5316.6
4½			7127.0	6337.4	6028.3
4¾			8268.3	7213.1	6802.3
5			9573.7	8183.5	7643.9
5¼				9259.7	8558.3
5½				10453.1	9553.9
5¾				11780.1	10638.4
6				13253.4	11819.8
6¼				14895.6	13108.8
6½					14513.4
6¾					16049.7
7					17728.0
7¼					19562.5
7½					21566.2

Basic orifice coefficients — Flange Taps

Base temperature = 60°F. Flowing temperature = 60°F.
Base pressure = 14.4 lb. per sq. in. Specific gravity = 0.60

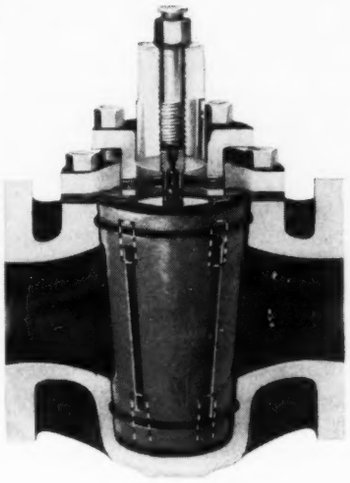
Orifice diameter in.	Pipe sizes—nominal and actual diameters				
	4-in. std. 4.026-in.	6-in. std. 6.065-in.	8-in. std. 8.071-in.	10-in. std. 10.136-in.	12-in. std. 12.090-in.
½	67.7	67.7			
¾	152.2	152.2			
1	270.6	270.6	270.6	270.6	
1¼	422.9	422.9	422.9	422.9	
1½	608.9	608.9	608.9	608.9	608.9
1¾	829.9	828.8	828.8	828.8	828.8
2	1099.3	1082.5	1082.5	1082.5	1082.5
2¼	1432.9	1370.0	1370.0	1370.0	1370.0
2½	1846.6	1691.5	1691.5	1691.5	1691.5
2¾		2054.8	2046.6	2046.6	2046.6
3		2471.9	2435.6	2435.6	2435.6
3¼		2952.4	2858.5	2858.5	2858.5
3½		3506.1	3319.3	3315.2	3315.2
3¾		4146.7	3829.6	3805.7	3805.7
4			4395.1	4330.0	4330.0
4¼			5025.3	4889.0	4888.2
4½			5726.6	5493.9	5480.3
4¾			6508.1	6149.4	6106.0
5			7378.7	6861.8	6765.7
5¼				7639.0	7468.4
5½				8483.7	8220.3
5¾				9403.9	9027.4
6				10408.2	9891.4
6¼				11502.9	10820.0
6½					11819.0
6¾					12890.1
7					14043.1
7¼					15281.3
7½					16610.8

the idea:

Simplicity Is Basic To Efficiency and Economy

One of the world's first valves, plug cocks invented by the Chinese centuries ago, had only one moving part—the plug. Even the earliest craftsman recognized the fact that simplicity of design almost always means a device that works better, lasts longer and costs less to use.

the application:



How It Helps Give You A Better Valve

In the modern Rockwell-Nordstrom lubricated plug valve there are only three rugged, basic parts . . . plug, body and cover. The plug is the only moving part. Compared to other valves, nothing could be simpler or more efficient. Yet the many advantages of simplicity are actually multiplied by *lubrication* in these valves. Pressurized lubrication jacks the plug, keeping it free for instant ¼-turn operation. It also forms an instantly replaceable, impenetrable seal against leakage, and prevents metal-to-metal wear.

the benefits:

Longer Valve Life At Lower Cost . . . Leak-proof Sealing . . . Reduced Down Time . . . Completely Protected Seating

The 6 million Rockwell-Nordstrom lubricated plug valves now used in a wide variety of industries are translating these benefits into dollars and cents savings day after day. Rockwell-Nordstrom is the most complete line of lubricated plug valves (sizes from ½" to 36"; pressures to 15,000 lb), lubricants and operating accessories. For *practical* help in solving your flow control problems, see your supplier or write: Rockwell Manufacturing Company, Dept. 103-H, Pittsburgh 8, Pa. Canadian Valve Licensee: Peacock Brothers Limited. If you live outside the U. S. or Canada, write: Rockwell International, S.A., Geneva, Switzerland.

Lubrication Makes The Difference

ROCKWELL-Nordstrom VALVES

another fine product by

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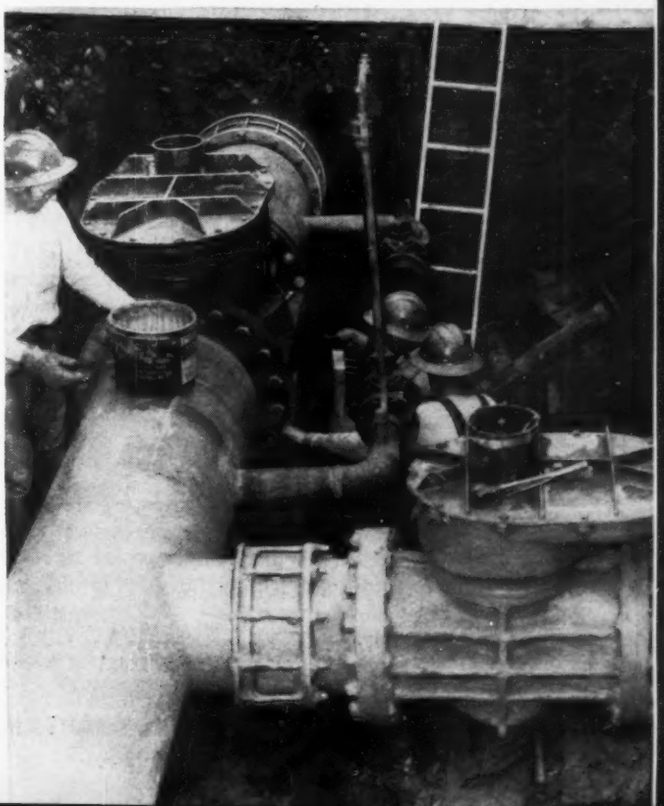
Buried Rockwell-Nordstrom valves (with water-tight gear housings) stay trouble-free. Lubrication is preventive maintenance against repairs and down-time.



Design of Large Volume Gas Measurement Facilities

THE measurement of the volume of gas delivered to large volume purchasers such as to secondary transmission systems, cities (via city gate stations) power plants and large industrial plants, is usually accomplished by using one of the following installations:

1. Positive displacement meters of large capacity, operating singly or in multiple (two or more in parallel).
2. Differential type orifice flow meters with simplex flow recorders, with or without automatic trip-over devices. By "simplex flow recorder" is meant a single range flow recorder (meters employing simplex flow recorders are herein referred to as "simplex orifice meters").
3. Differential type orifice flow meter with duplex flow recorder in one orifice run, or in the first of several orifice runs with trip-over devices (using simplex flow recorders in the balance of the orifice runs). By "duplex flow recorder" is meant a dual range flow recorder which usually consists of two single range recorders acting together—one for low range operation, and one for high range operation (meters employing duplex flow recorders are herein referred to as "duplex orifice meters").
4. Positive displacement meters replacing the differential type orifice flow meter in the first run of a multiple orifice run installation, with trip-over devices.

The type of metering equipment to be installed depends upon requirements to be met, particularly the requirements concerning maximum and minimum flow.

Positive Displacement Meters are used singly or in parallel:

1. Where minimum volume flows approach zero.
2. Where maximum volume flows are comparatively small.

Simplex Differential Type Orifice Flow Meters are used singly or in parallel:

1. Where minimum volume flows to be measured are not too critical.
2. Where maximum volume flows are comparatively large.

Duplex Differential Type Orifice Flow Meters are used either alone or in parallel with simplex type meters:

1. Where minimum volume flows to measured are more critical than can be handled on a simplex meter.
2. Where maximum volume flows are comparatively large.

Positive Displacement Meters are used in parallel with simplex differential type meters:

1. Where minimum volume flows approach zero.
2. Where maximum volume flows are comparatively large.

A 100-in. simplex flow recorder is accurate over a range from approximately 6 to 96-in., and has a flow ratio of approximately 4 to 1.

A 20-in. and a 100-in. flow recorder used in a duplex setting has a range from approximately 2 to 96-in. and has a flow ratio of approximately 7 to 1.

A 10-in. and a 100-in. flow recorder used in duplex setting has a range from approximately 1 to 96-in. or a flow ratio of approximately 10 to 1.

The flow ratios shown above will apply only to the first run in a multiple meter run installation inasmuch as allowances for proper operation of trip-over devices results in lower flow ratios for the succeeding runs.

Developed by John P. Evers, Mechanical Engineer, Ebasco Services, Inc., New York, New York, and R. W. Tirrell, Manager — Engineering Services and Drafting, Chemical Construction Corporation, New York, New York.

A positive displacement meter has a flow range from zero to the full capacity of the meter. For purposes of comparison with an orifice flow meter the positive displacement meter can be considered as a meter having a range from 0 to 96 inches, and an infinite flow ratio.

For each particular installation the engineer must select the most economical and efficient measurement equipment for the service intended. This involves the determination of minimum and maximum flows to be measured, the study of growth requirements, operating pressures, and other pertinent facts.

Orifice Flow Meters

The basic formula for measurement of gas flow by an orifice meter is:

$$Q_h = C' \sqrt{h_w p_f} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Where:

Q_h = rate of flow at base conditions in cu ft per hr
C' = orifice flow constant
h_w = orifice pressure differential in inches of water
p_f = absolute static pressure in psi

In the above equation

$$C' = F_b \times F_r \times Y \times F_{pb} \times F_{tb} \times F_{tf} \times F_g \times F_{pv} \times F_m \quad . \quad (2)$$

Where:

F_b = basic orifice flow factor
F_r = Reynold's number factor
Y = expansion factor
F_{pb} = pressure base factor
F_{tb} = temperature base factor
F_{tf} = flowing temperature factor
F_g = specific gravity factor
F_{pv} = supercompressibility factor
F_m = manometer factor*

For purposes of *preliminary* design the factors F_r, Y, F_{pv} and F_m can be neglected, and the remaining factors F_{pb}, F_{tb}, F_{tf} and F_g become constants for the particular design conditions.

Letting $$C'' = F_{pb} \times F_{tb} \times F_{tf} \times F_g \quad . \quad . \quad . \quad . \quad (3)$$

the flow formula for *preliminary design purposes only*, becomes

$$Q_h = F_b \times C'' \sqrt{h_w P_f} \quad . \quad . \quad . \quad . \quad (4)$$

In design, where several meter runs are to be operated in parallel, the total maximum flow can be represented by the formula:

$$Q_H = F_B \times C'' \sqrt{h_w P_f} \quad . \quad . \quad . \quad . \quad (5)$$

Where:

$$F_B = F_{b_1} + F_{b_2} + F_{b_3} \ldots \text{etc.}$$

and F_{b_1}, F_{b_2}, and F_{b_3} represent the basic orifice factors of each individual run in the multiple installation.

In meter station design, it is common practice to use orifice plates with standard bores which vary in multiples of ⅛-in. and ¼-in. according to size of meter run involved. Since the basic orifice factor is established by these standard orifices it is advisable to provide leaway in design calculations so that the final design will handle the total flow requirements. Therefore, in preliminary design calculations it is recommended that the maximum flow requirements be increased 10 per cent and equation (5) can be revised and rewritten as follows:

$$C'' = \frac{1.1 \quad Q_H}{F_B \sqrt{h_w p_f}} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

While it might be felt that the 10 per cent increase in the maximum flow requirements will result in a larger size installation than necessary, the practice of selecting orifices

*As it appears in AGA Gas Measurement Committee Report No. 3.

having a basic orifice factor equal to or slightly less than the required basic orifice factor (which has been calculated) results in a system having a capacity close to the specified requirements.

It is common practice when several meter runs are operated in parallel, for the installation to be provided with a mechanical means of increasing or decreasing the number of meter runs in service. This is done in order to adapt the installation to varying flow requirements. Thus, as the flow is increased from minimum to maximum, one or more meter runs will be successively added to the initial run. Likewise, as the flow rate decreases from maximum to minimum these additional runs are cut out of service until only the initial run remains in operation. The adding or subtracting of each successive meter run is performed by a trip valve which operates automatically to add or subtract a meter run at preset maximum and minimum flow ratio. In order to provide proper sequence of operation, these maximum and minimum flows must be established for each individual meter run, for it is essential that the trip points selected permit **only** the designated meter run to operate.

In developing "work sheets" for the design of a multiple run 100 inch simplex orifice meter installations, the following assumptions apply to all designs:

(1) The minimum accurate recordable flow differential for a 100-in. simplex flow meter is 6-in. of water.

(2) The upper trip point in **all** meter runs in a multiple run installation is to be set at a differential of 96-in.

(3) The lower trip point in a multiple run installation is to be set at a differential of 6.5-in. in Run No. 1, 8.0-in. in Run No. 2, and 9.5-in. in Run No. 3.

(4) A flow causing a differential of 96-in. in one meter run will cause a differential of 7.5-in. in two parallel runs; a flow causing a differential of 96-in. in two parallel meter runs will cause a differential of 9.0-in. in three parallel meter runs; and a flow causing a differential of 96-in. in three parallel meter runs will cause a differential of 10.5-in. in four parallel meter runs, etc.

(5) The ratio of maximum to minimum flow in each meter run is the square root of the maximum differential (96-in.) divided by the square root of the minimum differential (as described in 4 above).

Assigning a value of 1.0 (unity) to the minimum flow for a single 100-in. simplex meter run (6.0-in. differential), and utilizing the previously stated assumptions, the following capacity calculations have been made for installations having multiple runs with trip-over valves:

Type of installation	Differential (In. of water)	*Flow capacity (Units)	Calculation
One run only	6.0	1.0	
	96.0	4.0	$\sqrt{\frac{96.0}{6.0}} \times 1.0 = 4.0$
Two runs in parallel	7.5	4.0	Same flow as above divided to two runs.
	96.0	14.3	$\sqrt{\frac{96.0}{7.5}} \times 4.0 = 14.3$
Three runs in parallel	9.0	14.3	Same flow as above divided into three runs.
	96.0	46.7	$\sqrt{\frac{96.0}{9.0}} \times 14.3 = 46.7$
Four runs in parellel	10.5	46.7	Same flow as above divided into four runs.
	96.0	141.3	$\sqrt{\frac{96.0}{10.5}} \times 46.7 = 141.3$

*Since the minimum flow of the first run was taken as unity, the maximum flow capacity calculated for a multiple run installation is also the maximum flow **ratio** for such an installation.

The maximum flow in each individual run can be readily determined by subtracting from the total capacity of the multiple installation, the 96-in. flow capacity unit values of all the runs except the last. This gives the following:

Run No.	Total capacity All runs	Total capacity All runs except last run	Capacity of last run
4	141.3	46.7	94.6
3	46.7	14.3	32.4
2	14.3	4.0	10.3
1	4.0	—	4.0

The maximum flow ratios and trip points calculated by the above method, are listed in Table No. 1. This table shows flow ratio data and trip point data for both "simplex" and "duplex" orifice flow meter installations having a maximum of four (4) parallel runs with a maximum total basic orifice factor (F_B) of approximately 40,000.

Table No. 1 also shows "K values" for each type of installation. These "K values" are constants, which, when multiplied by the maximum flow for which the entire installation is to be designed, gives the maximum flow requirements for each individual run to be used in the installation. In design calculations, the "K values" are used as multipliers of the total basic orifice flow factor for the entire installation (F_B) to obtain the basic orifice flow factor of each individual run (F_{b_1}, F_{b_2}, etc.).

Calculations and procedures discussed in the preceding paragraphs cover "simplex" meter installations only. The development of capacities and ratios for installations having a duplex meter in the first run is basically the same as for installations having a simplex meter in the first run. Table I shows design data for both "simplex" and "duplex" installations.

Positive Displacement Meters

The design of installations that use positive displacement meters **only**, operating singly or in parallel, presents no un-

TABLE 1.

Maximum flow ratio			Number of meter runs	Trip point (Inches water)		K Value Meter run			
Simplex	Duplex type A	Duplex type B		Min.	Max.	1	2	3	4
4.0									
	7.0		1	6.5	96.0	1.000	—	—	—
		10.0							
14.3									
	25.0		2	8.0	96.0	0.280	0.720	—	—
		35.8							
46.7									
	81.8		3	9.5	96.0	0.085	0.221	0.694	—
		116.6							
141.3				—	—	0.028	0.073	0.229	0.670
	247.3		4						
		353.3							

The systems listed above as "Simplex" have 100-in. differential type flowmeters in all runs.

The systems listed as "Duplex-Type A" have 20-in. and 100-in. meters in the first run, and 100-in. meters in all additional meter runs.

The system listed as "Duplex-Type B" have 10-in. and 100-in. meters in the first run, and 100-in. meters in all additional meter runs.

Maximum flow ratios are based on constant meter run pressures at both high and low flow rates. If meter run pressure is not controlled, these factors must be changed by ratio of square roots of absolute pressures at low and high flow conditions.

usual problems. When a positive displacement meter is used in the first run of a multiple run installation employing differential type meters, it has been found desirable to establish a definite procedure for the design of the installation. The recommended procedure is given in Section III, Part 3 of the "work sheets", and covers the determination of an economical installation having its first run capacity within the limits of an available standard size positive displacement meter.

Work Sheets

The following "work sheets" have been developed based on the design theories previously expressed. The "work sheets" make no attempt to explain each step of the calculation, it being expected that engineers using these "work sheets" will be familiar with basic flow meter system requirements and calculations, and the necessary data books will be available for their use.

CALCULATED BY A.B.C.
DATE 11-15-56
CHECKED BY D.E.F.

GAS FLOW METER CALCULATIONS
WORK SHEET NO 1 OF 4

I DESIGN CONDITIONS:

Maximum quantity of gas to be metered (q_H)	200,000	SCFH
Minimum quantity of gas to be metered (q_L)	2,000	SCFH
Specific gravity of gas, relative to air (SG)	0.60	
Flowing pressure (P)	100	PSIG
Flowing temperature (T)	65	°F
Pressure base (contract)	14.4	PSIA
Temperature base (contract)	60	°F

II TOTAL BASIC ORIFICE FLOW FACTOR (F_b) CALCULATIONS:

Determine total basic orifice factor as follows:

$$F_b = \frac{1.1\ q_H}{C'\sqrt{h_w P_f}}$$

F_b = total basic orifice flow factor = F_{b_1} F_{b_2} F_{b_3} etc.

(F_{b_1}, F_{b_2}, etc. are basic orifice coefficients for individual meter runs)

q_H = maximum quantity of gas to be metered (from design conditions)

F_{pb} = pressure base factor (14.4 PSIA = 1)**	1.0
F_{tb} = temperature base factor (60°F = 1)	1.0
F_{tf} = flowing temperature factor (60°F = 1)	.9952
F_g = specific gravity factor (SG 0.60 = 1.291).	1.291
C' = $F_{pb} \times F_{tb} \times F_{tf} \times F_g$ (for preliminary calculations) =	1.285

h_w = 96 in., maximum

P_f = P + 15 = 115

$\frac{h_w P_f}{\sqrt{h_w P_f}}$ = $\frac{11,040}{105}$

$$F_b = \frac{1.1\ q_H}{C'\sqrt{h_w P_f}} = \frac{1.1 \times (200,000)}{(1.285) \times (105)} = 1630.0$$

* F_b increased 10% for flexibility of design
** See tables in this handbook for conversion factors

CALCULATED BY A.B.C.
DATE 11-15-56
CHECKED BY D.E.F.

GAS FLOW METER CALCULATIONS
WORK SHEET NO 2 OF 4

Column Number	1	2	3
Type of Installation	1 P D Run 1 Simplex Run	1 P D Run 2 Simplex Runs	1 P D Run 3 Simplex Runs
Equation For Required Capacity in P D Meter	= 4 x Max. Flow / 14.3	= 4 x Max. Flow / 48.7	= 4 x Max. Flow / 141.3
Required Capacity, SCFH	56,000	17,150	
Manufacturer	Not Manufactured	XYZ Meter Co.	
Model No.		20-A	
Rated Capacity at Flow Conditions		20,000 SCFH	

4) After considering economy, provision for future expansion, and general conditions affecting the installation, select from the preceding tables the metering system to be used. List below the system selected.

Number of runs 3

Meter(s) for initial (check) meter run (one)

- ☐ Simplex (100")
- ☐ Duplex Type A (20" and 100")
- ☑ Duplex Type B (10" and 100")
- ☐ Positive displacement

Basis of selection: Installation costs will be kept to a minimum if either a PD meter or a Duplex Type B meter is used in the first meter run.

CALCULATED BY A.B.C.
DATE 11-15-56
CHECKED BY D.E.F.

GAS FLOW METER CALCULATIONS
WORK SHEET NO 3 OF 4

III SELECTION OF METERING SYSTEM

1) Calculate the maximum flow ratio for the proposed installation as follows:

Maximum Flow Ratio = Maximum quantity of gas to be metered / Minimum quantity of gas to be metered

$$= \frac{q_H}{q_L} = \frac{200,000}{2,000} = 100$$

2) For the above calculated flow ratio, select the total minimum number of meter runs required for each of the three types of installations listed on Table No. 1 and complete the following

	Type of Installation	Simplex	Duplex Type A	Duplex Type B
	Calculated Maximum Flow Ratio	100	100	100
	Tabulated Maximum Flow Ratio**	141.3	247.3	116.6
Meter Runs	Total - Minimum No. of Runs Req'd**	4	4	3
	Less - No. of Duplex Runs	0	1	1
	Equals - No. of Simplex Runs Req'd	4	3	2

**From Table 1.

3) If a positive displacement meter is required in the first run of a multiple run installation, the following tabulation should be used to determine the number of meter runs and size of meter required. Columns 1, 2, and 3 of the table should be successively calculated to determine the capacity (at flow conditions) of a standard size positive displacement meter for installation in the first run.

CALCULATED BY A.B.C.
DATE 11-15-56
CHECKED BY D.E.F.

GAS FLOW METER CALCULATIONS
WORK SHEET NO 4 OF 4

IV. COMPLETION OF DESIGN:

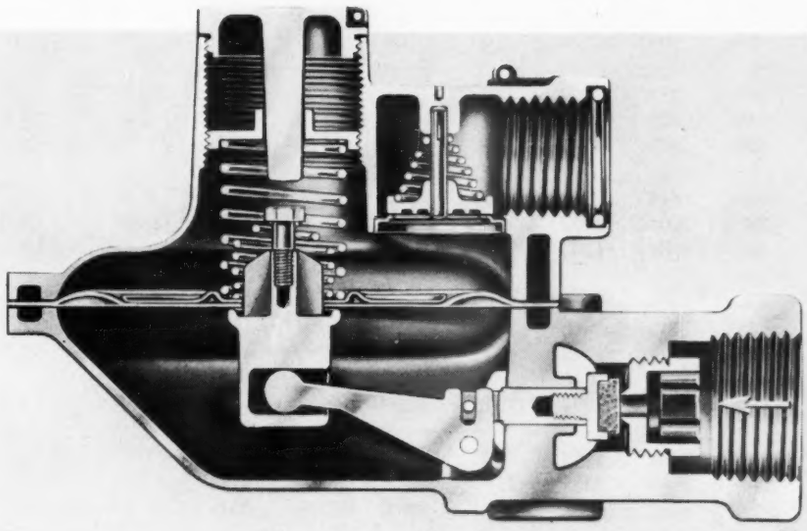
Complete design on chart using data given on Table 1, and preceding calculations.

Meter Run		1 1	2 2	3 3	4 4
Total Orifice Factor F_b (from Sheet No. 1)		1630	1630	1630	
K Factor (from Table No. 1)		.085	.221	.649	
F_b theoretical (F_b x K Factor)		138.5	373.0	1059.9	
Type of Taps (Flange or pipe)		FT	FT	FT	
F_b actual - selected from handbook		162.11	402.10	1114.9	
ID of Meter Run, Inches		2.067	3.068	4.026	
Orifice Bore, Inches		.875	1.375	2.250	
Beta Ratio		.423	.449	.559	
Individual Run	Minimum Flow, SCFH	1980	12,800	39,500	
	Low Trip Point, Inches	6.5	8.0	—	
	Maximum Flow, SCFH	19,800	49,200	136,800	
	High Trip Point, Inches	96	96	—	
Cumulative	Minimum Flow, SCFH	1980	18,000	59,400	
	Maximum Flow, SCFH	19,800	69,000	205,800	

V. DESIGN COMMENTS: If a large future growth is probable with a corresponding increase in the minimum flow requirements, a 6.065-inch ID meter run with 2.375-inch orifice bore (Beta Ratio = 0.392) should be used in Run #3 in place of the 4.026 ID run shown.

The Leader Leads Again...

FISHER ANNOUNCES A NEW LOW COST SERVICE REGULATOR



SERIES

S250

HANDLES 99% OF ALL DOMESTIC INSTALLATIONS

Good news for the gas industry! Fisher now offers a new domestic service regulator designed especially for installations requiring 250 CFH regulating capacity or less. The new Series S250 is not only lower in cost due to the compact design, but it meets the requirements of 99% of all domestic installations.

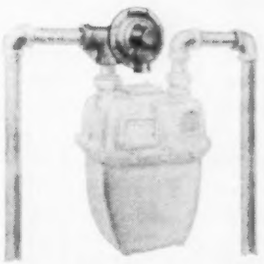
Capacity-wise, the Fisher S250 service regulator is the companion of the compact meters now available. This enables you to make a LOWER COST, COMPLETE customer service.

The Series S250 consists of Type S251 standard regulator with compact screened vent (no internal relief valve) and Type S252 with full capacity internal relief valve and large weather-proof vent.

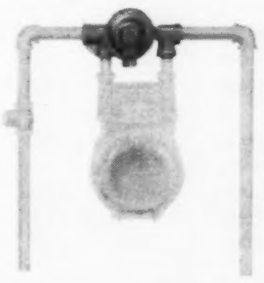
Aluminum body and lower casing are one piece construction. The "elbow" type body reduces your installation costs.

Design features body sizes ¾ and 1" with orifice size ⅛, 3/16, ¼, ⅜".

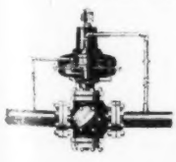
Capacity 250 CFH or more with or without full capacity internal relief. Suitable for upstream pressures up to 100 psi and springs available for reduced pressures from 3½" W.C. to 15" W.C.



The S250 meets the growing demand for a compact, low cost service regulator to match the small meters now being put into service. It simplifies installation problems and lowers installation costs.



The S250 regulator with integral meter bar provides the ultimate in low cost piping hook up.



IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD... CHANCES ARE IT'S CONTROLLED BY...

FISHER GOVERNOR COMPANY

Marshalltown, Iowa / Woodstock, Ontario / London, England

BUTTERFLY VALVE DIVISION: CONTINENTAL EQUIPMENT CO., CORAOPOLIS, PENNSYLVANIA

FISHER® Controls

SINCE 1880

Temperature Conversion Table

°C	0	10	20	30	40	50	60	70	80	90
	F	F	F	F	F	F	F	F	F	F
—200	—328	—364	—364	—382	—400	—418	—436	—454	....	....
—100	—148	—166	—184	—202	—220	—238	—256	—274	—292	—310
—0	+32	+14	—4	—22	—40	—58	—76	—94	—112	—130
0	32	50	68	86	104	122	140	158	176	194
100	212	230	248	266	284	302	320	338	356	374
200	392	410	428	446	464	482	500	518	536	554
300	572	590	608	626	644	662	680	698	716	734
400	752	770	788	806	824	842	860	878	896	914
500	932	950	968	986	1004	1022	1040	1058	1076	1094
600	1112	1130	1148	1166	1184	1202	1220	1238	1256	1274
700	1292	1310	1328	1346	1364	1382	1400	1418	1436	1454
800	1472	1490	1508	1526	1544	1562	1580	1598	1616	1634
900	1652	1670	1688	1706	1724	1742	1760	1778	1796	1814
1000	1832	1850	1868	1886	1904	1922	1940	1958	1976	1994
1100	2012	2030	2048	2066	2084	2102	2120	2138	2156	2174
1200	2192	2210	2228	2246	2264	2282	2300	2318	2336	2354
1300	2372	2390	2408	2426	2444	2462	2480	2498	2516	2534
1400	2552	2570	2588	2606	2624	2642	2660	2678	2696	2714
1500	2732	2750	2768	2786	2804	2822	2840	2858	2876	2894
1600	2912	2930	2948	2966	2984	3002	3020	3038	3056	3074
1700	3092	3110	3128	3146	3164	3182	3200	3218	3236	3254
1800	3272	3290	3308	3326	3344	3362	3380	3398	3416	3434
1900	3452	3470	3488	3506	3524	3542	3560	3578	3596	3614
2000	3632	3650	3668	3686	3704	3722	3740	3758	3776	3794
2100	3812	3830	3848	3866	3884	3902	3920	3938	3956	3974
2200	3992	4010	4028	4046	4064	4082	4100	4118	4136	4154
2300	4172	4190	4208	4226	4244	4262	4280	4298	4316	4334
2400	4352	4370	4388	4406	4424	4442	4460	4478	4496	4514
2500	4532	4550	4568	4586	4604	4622	4640	4658	4676	4694
2600	4712	4730	4748	4766	4784	4802	4820	4838	4856	4874
2700	4892	4910	4928	4946	4964	4982	5000	5018	5036	5054
2800	5072	5090	5108	5126	5144	5162	5180	5198	5216	5234
2900	5252	5270	5288	5306	5324	5342	5360	5378	5396	5414
3000	5432	5450	5468	5486	5504	5522	5540	5558	5576	5594
3100	5612	5630	5648	5666	5684	5702	5720	5738	5756	5774
3200	5792	5810	5828	5846	5864	5882	5900	5918	5936	5954
3300	5972	5990	6008	6026	6044	6062	6080	6098	6116	6134
3400	6152	6170	6188	6206	6224	6242	6260	6278	6296	6314
3500	6332	6350	6368	6386	6404	6422	6440	6458	6476	6494
3600	6512	6530	6548	6566	6584	6602	6620	6638	6656	6674
3700	6692	6710	6728	6746	6764	6782	6800	6818	6836	6854
3800	6872	6890	6908	6926	6944	6962	6980	6998	7016	7034
3900	7052	7070	7088	7106	7124	7142	7160	7178	7196	7214
°C	0	10	20	30	40	50	60	70	80	90

°C	°F
1	1.8
2	3.6
3	5.4
4	7.2
5	9.0
6	10.8
7	12.6
8	14.4
9	16.2
10	18.0

°F	°C
1	1.56
2	1.11
3	1.67
4	2.22
5	2.78
6	3.33
7	3.89
8	4.44
9	5.00
10	5.56
11	6.11
12	6.67
13	7.22
14	7.78
15	8.33
16	8.89
17	9.44
18	10.00

Examples: 1347° C = 2444° F +12.6° F = 2456.6° F. 3367° F = 1850° C + 2.78° C = 1852.78° C.

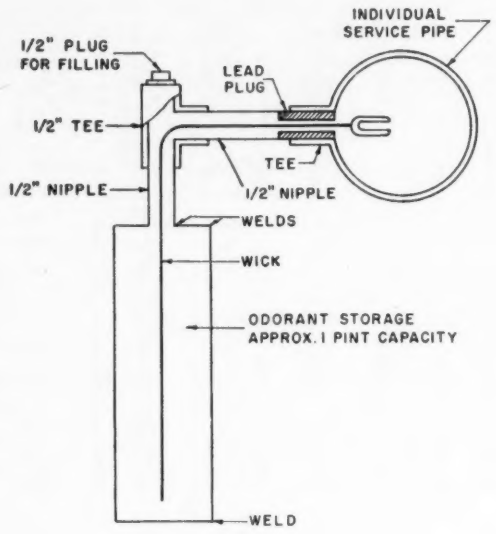
Bureau of Standards—M126

Properties of Odorants for Natural Gas

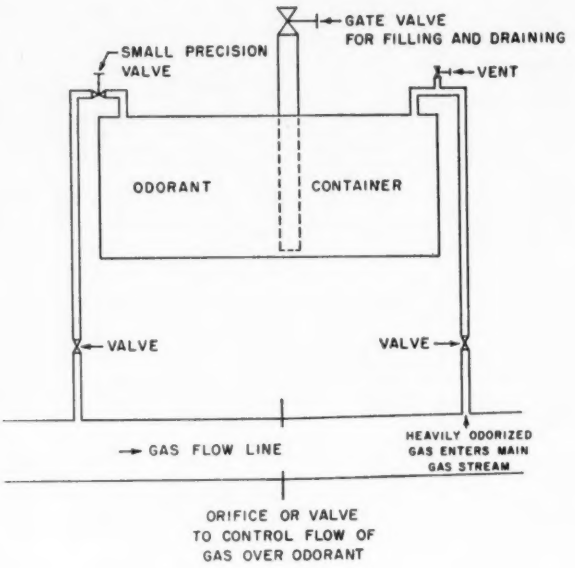
(As of August, 1959, based on data supplied by the manufacturers)

Name of Odorant and Manufacturer	Specific Gravity (60/60 F)	Mol. Wt. (avg.)	Weight Per Gal (lb)	Viscosity Centistokes at 77 F	Reid Vapor Pressure (psi at 100 F)	Distillation	Volatility (lb/MMcf) @0°F & 1000 psi	Cloud Point (max.)	Freezing Point	Flash Point (Open Cup)	Mercaptan Content (% by vol.)	Sulfur Content (% by wt.)	Toxicity*	Solubility in Water (% by vol.)	Recommended Odorizing Rate (lb/MMcf)	Sulfur Contribution (gr/100 cu ft)
NATURAL GAS ODORIZING COMPANY																
Captan	0.825	82	6.88	—	8.2	IBP—125 F 95%—250 F EP—340 F	210	—20 F	Below —100 F	20 F	90	36	"a"	Trace	0.25 to 1.0	0.25
BP Captan	0.810	86	6.75	—	5.0	IBP—138 F 95%—160 F EP—220 F	350	—20 F	Below —60 F	20 F	99+	37	"a"	Trace	.25 to 1.0	0.26
RP Captan	0.815	86	6.8	—	8.1	IBP—115 F 95%—300 F EP—360 F	70	—20 F	Below —60 F	20 F	80	37	"a"	Trace	0.25 to 1.0	0.26
"99" Captan	0.825	82	6.88	—	6.8	IBP—130 F 95%—200 F EP—340 F	100	—20 F	Below —100 F	20 F	99+	36	"a"	Trace	0.25 to 1.0	0.25
DL Captan	0.723	84	6.0	—	8.0	IBP—100 F 95%—250 F EP—290 F	28	—10 F	Below —100 F	0° F	10	4.1	"a"	Trace	1.5 to 6.0	0.173
GasNIFF	0.830	104	6.92	—	1.4	IBP—200 F 95%—206 F EP—210 F	4.5	—20 F	Below —100 F	55 F	Nil	31	"a"	Trace	0.50 to 1.0	0.22
TB Captan	0.818	84	6.82	—	4.2	IBP—136 F 95%—180 F EP—225 F	500	—20 F	Below —60 F	20 F	99+	36	"a"	Trace	0.25 to 1.0	0.25
DL Captan	0.723	84	6.0	—	8.0	IBP—100 F 95%—250 F EP—290 F	28 gal/MMcf	—10 F	Below —100 F	0° F	10	4.1	"a"	Trace	0.25 to 1.0 (gal/MMcf)	0.173
CL Captan	0.723	84	6.0	—	11.5	IBP—100 F 95%—340 F EP—360 F	24 gal/MMcf	—10 F	Below —100 F	0° F	Trace	4.1	"a"	Trace	0.25 to 1.0 (gal/MMcf)	0.173
PENNSALT CHEMICALS CORPORATION, INDUSTRIAL DIVISION																
Spotleak 1008	0.82	91	6.8	0.52	6.2	IBP—120 F 95%—270 F	230@ 40 F & 720 psi	—20 F	Below —50 F	Below 0° F	94 (Min.)	33 (Min.)	"a"	0.060	0.25 to 1.00	0.058 to 0.232
Spotleak 1009	0.81	86	6.7	0.64	6.2	IBP—120 F 95%—180 F	370@ 40 F & 720 psi	—20 F	Below —50 F	Below 0° F	94 (Min.)	35 (Min.)	"a"	0.040	0.25 to 0.75	0.061 to 0.183
Cyclic Sulfide Odorant 1013	1.00	88	8	0.94	1.0	IBP—239 F 95%—252 F EP—256 F	50@ 40 F & 720 psi	—20 F	Below —90 F	55 F	None	37 (Max.)	"a"	Insoluble	0.45 to 0.80	0.114 to 0.203
Spotleak 1015	0.807	85	6.7	0.84	8.0	IBP—113 F 98%—158 F	135@ 0° F & 1000 psi	—20 F	Below —50 F	Below 0° F	99 (Min.)	36 (Min.)	"a"	0.20	0.5	0.13
MARSHALL HYDE																
Formula 55	0.777	90	6.48	—	7.0	IBP—134 F 95%—147 F EP—154 F	—	—35 F	Below —55 F	—	85	29.8 (Max.)	"a"	—	0.25 to 0.50	0.1 to 0.2
ORONITE CHEMICAL COMPANY																
Calodorant "C"	1.00	88	8.3	0.94	1.0	IBP—231 F 95%—250 F EP—270 F	7.2	—	Below —150 F	64 F	Nil	37	"a"	0.07	0.5 to 1.0	0.13 to 0.26
Calodorant "C" Special	0.878	95	7.3	0.82	1.3	IBP—112 F 95%—340 F EP—360 F	3.4	—	Below —150 F	80 F	Trace	20.6	"a"	0.06	1.0	0.14
Alert 80	0.829	77	6.9	0.44	9.0	IBP—110 F 95%—184 F EP—265 F	12.5	—	Below —150 F	32 F	95+	42	"a"	0.38	0.5 to 1.0	0.15 to 0.30
LPG	0.816	76	6.8	0.40	12.0	IBP—124 F 95%—130 F EP—145 F	—	—	Below —150 F	32 F	99+	42	"a"	0.26	0.5 to 1.0	0.15 to 0.30
Calodorant B-1	0.839	105	7.0	0.51	2.0	IBP—184 F 95%—286 F EP—290 F	6.1	23 F	Below —150 F	36 F	Trace	32	"a"	0.10	0.5 to 1.0	0.11 to 0.21
Calodorant "F"	0.849	64	7.0	0.34	14.5	IBP— 98 F 95%—124 F EP—182 F	220	—	Below —150 F	Below —30 F	Trace	49.2	"a	1.56	0.5 to 1.0	0.17 to 0.34
Oronite Ethyl Mercaptan	0.844	62	7.0	0.26	16.5	IBP— 94 F 95%— 97 F EP— 98 F	—	—	Below —150 F	32 F	99+	52	"a"	0.70	Not applicable	Not applicable

*"a"—indicates non-toxic at normal odorization levels.



Wick type odorizer.



By-pass type odorizer.

Odorization of Natural Gas

THE lower explosive limit of natural gas is approximately 4 parts of gas and 96 parts of air. This explosive limit varies with the contents of the gas. Gas containing butane and propane mixtures in vapor form have a slightly lower explosive limit.

Odorants are added to natural gas to make possible its detection in mixtures below the lower explosive limit. Generally accepted practices of odorization require that the odor must be discernable in mixtures of from one half to one per cent of gas in air.

Two major types of odorants are in common use at the present time. These are known as **dilute** and **concentrated** odorants. The quantity of either type of odorant to be used can be determined only by a study of the conditions existing where it is to be injected into the gas.

Dilute odorants are used generally where the gas load is small, and the quantity of odorant handled is not a problem. Different odorants in this classification have varying characteristics, and should be injected within the ranges of manufacturers' recommendations.

Concentrated odorants are particularly adapted to large installations and by-pass odorizers. The proper odorant should be used for the type of equipment installed, as the concentration of the odorant will produce additional operating problems if improperly injected. The quantity of odorant used should be within the limits of manufacturers' recommendations and should be sufficient to provide a strong odor at the extremities of the system.

Odorizing equipment can be roughly classified into divisions as follows, with variations in each division, depending upon local conditions and standards:

Wick Type Odorizer

This odorizer is particularly adapted to use where the odorizers must be installed on individual meters. This odorizer does not give proportional odorization because it is affected by the temperature and volatility of the odorant rather than by the gas load. The temperature effects on this odorizer can be reduced by surrounding it with asbestos insulation. Some insulation can be obtained by painting the odorizer with aluminum paint, or by protecting it from direct sunlight.

It may be necessary to drain the odorizer periodically in order to remove any accumulated heavy ends of odorant. The wick type odorizer is not recommended for larger installations where proportional odorization can be obtained by other methods. Either dilute or concentrated odorant can be used, as the odorant output is regulated by the amount of wick extending into the gas stream. Dilute odorant is generally preferred.

By-Pass Type Odorizer

This type odorizer will give porportional odorization under a wide range of loading, if properly designed and installed.

ORONITE®

your most complete gas odorant source

Odorant products

Calodorant® "C" — best quality sulfide type odorant
Calodorant® B-1 — a sulfide odorant at a mercaptan price
Calodorant F — a low boiling, economy priced sulfide odorant
Alert® "80" — best economy priced, quality mercaptan odorant
Alert 101 — new tertiary-butyl mercaptan based odorant
LPG Odorant — tailor made from a selected mercaptan cut
Ethyl Mercaptan — an odorant of highest quality and purity

Manufacturing facilities

Oronite has its own odorant production facilities at two large manufacturing centers—Richmond, California and Oak Point, Louisiana—both located close to principal gas consuming areas.

Distribution centers

Oronite odorant products are warehoused at key points throughout the nation to assure you prompt delivery and service.

Research, technical service

Oronite maintains a technical field service staff of odorant specialists who can work closely with you in solving unique or individual problems. The field technical service staff is backed by a continuous research and development program to maintain Oronite's position as the foremost supplier of odorants to the gas industry.

A phone call or letter to any Oronite office will promptly bring an odorant specialist to consult and assist you on gas odorization

ORONITE CHEMICAL COMPANY
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SALES OFFICES • New York, Boston, Wilmington, Chicago, Cincinnati, Cleveland, Houston, Tulsa, Los Angeles, San Francisco, Seattle
Foreign Affiliate: California Chemical International, Inc., San Francisco, Geneva, Panama

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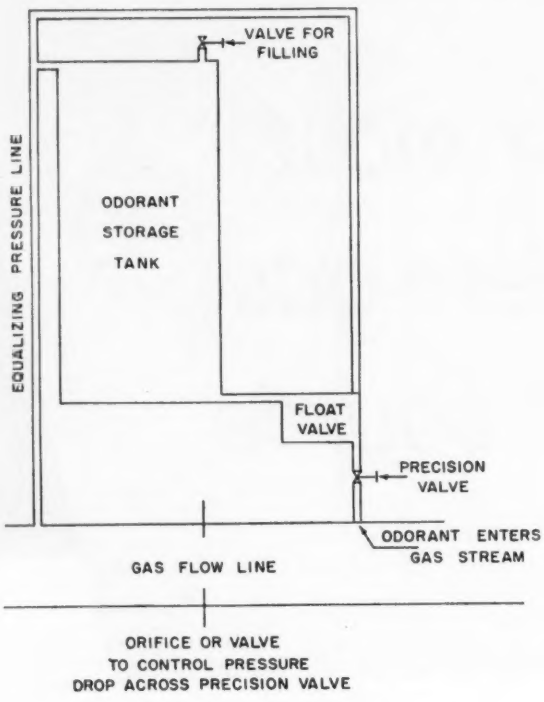
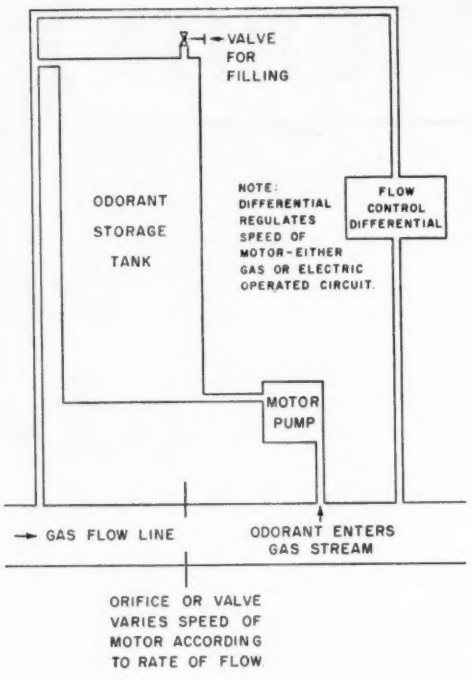


Proportional drip type odorizer.


VALVE FOR FILLING
ODORANT STORAGE TANK
NOTE: DIFFERENTIAL REGULATES SPEED OF MOTOR - EITHER GAS OR ELECTRIC OPERATED CIRCUIT.
FLOW CONTROL DIFFERENTIAL
MOTOR PUMP
GAS FLOW LINE
ODORANT ENTERS GAS STREAM
ORIFICE OR VALVE VARIES SPEED OF MOTOR ACCORDING TO RATE OF FLOW

Liquid injection type odorizer.

It has no moving parts to get out of adjustment. Temperature variation of the odorant must be kept at a minimum, and it is recommended that the by-pass odorizer be installed underground with a minimum of two feet of cover. If possible it should be installed below (not across) a regulator in order to insure a constant pressure on the odorizer.

Liquid hydrocarbons entrapped in the gas will contaminate the odorant in a by-pass odorizer, reducing the volatility of the mixture, and slowing down the rate of odorization. Most gas from pipe line systems has had these liquids removed, so this problem generally exists only near gas fields.

The rate of flow is regulated by a small precision valve in the gas flow line over the odorant. A small pressure differential is maintained in the gas main, across a valve or orifice plate. Since the parallel flow in the two lines always remains proportional, the rate of odorization remains constant regardless of load (assuming constant pressure and temperature). No baffles or wicking should be installed in the odorizer, as the amount of gas passing over the odorant is very small in comparison to the ability of the odorant to be absorbed into the gas stream.

The odorant used in the by-pass odorizer must be blended especially for this type odorizer. It should be a concentrated odorant with a very narrow range from initial to final billing point. If the proper odorant is used, there should be no accumulation of heavy ends in the odorizer, but a connection to the bottom of the odorizer may prove valuable in case the odorant becomes contaminated.

Proportional Drip Type Odorizer

The elementary proportional drip type odorizer consists of a storage tank for odorant, a float valve to regulate the flow of odorant through a precision valve, and equalizing lines across a restriction in the gas main. This odorizer requires more pressure drop across the restriction than does the by-pass type. The precision valve acts as an orifice to keep the flow of liquid odorant and gas proportional. The float valve keeps a constant level of liquid on the precision valve, regardless of the quantity of odorant in storage.

This odorizer will operate with either dilute or concentrated odorant. At exeremely low rates of flow, it is necessary to cut down the flow of liquid through the precision valve to such an extent that stoppage may result, or the float valve may build up sufficient pressure to cause the odorant to flow when the gas flow has practically stopped, causing excess odorization. Under these conditions, better results may be secured if a dilute odorant is used.

The proportional drip type odorizer operates across a restriction in the gas line, and the precision valve controls the rate of odorization. Other features can be added if desired, to secure accurate rates of flow. Modifications of the odorizer have value under certain conditions. One modification permits the use of the storage tank as a by-pass odorizer during periods of low flow.

Liquid Injection Type Odorizer

A positive method of injecting odorant by means of a proportioning pump is in use. One odorizer uses a small, extremely accurate pump, which is installed in such a manner that it injects odorant proportionally to the load.

Another type has a proportionate amount of gas passing through a positive meter, activating a rotary cup, which dips odorant from a pan where the odorant level is kept constant by a float valve. The odorant is then dripped into the gas flow line in proportion to the load on the main line.

This type equipment will work with a variety of odorants, but since there are moving parts to stick, special attention must be paid to having a properly designed and clean odorant.

Conclusion

A properly blended odorant should give odorization thruout the entire system. The amount of sulfur in it is not sufficient to cause damage to gas meters or other equipment. The amount of sulfur added to the gas through odorization is far below the amounts of impurities carried in the normal gas stream.

Line Conditioning of New Service Mains

It is advisable to condition new service mains prior to their use in a distribution system. All odorants are adsorbed on new pipe to a more or less degree, dependent upon the type of odorant. Generally, because the sulfide odorants are less reactive, chemically, their adsorption rate is less than the mercaptan type odorants, and the conditioning of the line is accomplished sooner.

There are two methods which can be used to condition new mains. In one method the odorant to be used is diluted with a high boiling point solvent such as kerosine, cleaning solvent, or unleaded white gasoline and injected into the line at a rate of from 3 to 5 gal per MMcf. The diluent acts as a coating on the inside surface of the line and retards further odorant adsorption or chemical reaction, enabling the odorant to pass through in detectable concentrations at the end of the line.

One large midwestern utility has done considerable test work on line conditioning and the results of their work have been reported and published in the Midwest Gas Association proceedings. Their method consists of purging the new main with normally odorized gas, then adding odorant to the gas passing through the line at an approximate rate of 22 lb per Mcf of pipe volume or about 3.8 lb per 1000 sq ft of inside pipe surface. The pressure of the gas in the main is maintained at from 5 to 7 psi. The heavily odorized gas is vented through a John Zink No. 2 burner to prevent the release of the odor to the atmosphere. This utility has used all types of odorants in their test work and favor the use of mercaptans, especially ethyl mercaptan because of its high volatility.

Periodic testing of the vent gas using an odorometer or a Titrilog is done to determine when the odorized gas has reached equilibrium and the line is conditioned and ready for service connections.

The amount of time necessary to condition a new line will be variable according to size, length, and type of pipe, rate of gas flow, and temperature.

Soil Adsorption

One of the principal deficiencies of all present day gas odorants is their inability to withstand the filtering action of all type soils when a gas leak occurs underground. All gas odorants are effectively scrubbed of their odor intensity when passing through the soil, regardless of type; clay, loam, sand or various mixtures of soils.

Only after sufficient odorized gas has passed through the soil to completely saturate the surrounding area or channel of the leak can the odorized gas be detected at the surface. The amount of time necessary to complete this cycle will depend upon the type of soil, degree of compaction, moisture content, volume of gas flow and the odorant content of the gas.

Odorant manufacturers and utilities have spent many man hours of research time and money trying to find a solution to this inherent problem of all odorants.

It has been claimed that manufactured gas was not adsorbed by soil and that an underground leak was readily detectable when it occurred. The odor character of manufactured gas was contributed by the relatively large volumes of aromatics that it contained. Because of these large volumes the soil around the leak was more quickly saturated, hence a leak was more readily detected. Natural gas containing only a minute part of odorant takes considerably longer time to saturate the leak channel and a longer time to be detectable at the surface.

Methods of Checking Odorant Intensity

Odor intensities may be rated by many scales using several degrees of intensity but in the field, only two levels of intensity are significant. These levels are:

Threshold — The concentration of odorized gas in air that produces the first change from the prevailing or normal odor.

Adequate — The concentration of odorized gas in air that produces enough odor to arrest attention and provide a warning.

The absolute intensity of these levels, of course, will vary, depending upon the average ambient odor; therefore, a single standard cannot be adopted. However, in all cases the concentration of gas in air for the adequate level should be well below explosive limit of gas (5 volume percent).

Odor intensities of gas have been measured by means of room tests, odorometers, or other devices. Room tests are designed to simulate the conditions under which leaks may occur. In this test odorized gas is metered into a closed room until a definite concentration of gas is reached and the odor is recorded by observers. This test may be used to obtain the *threshold* and *adequate* values by running the tests at different gas concentrations, or it may be used to compare different odorants at a fixed gas and odorant concentration. A big disadvantage of this method is its lack of portability.

Several chemical methods can be used for determining the sulfur content of a gas stream, but only one appears to be easily adaptable to a continuous testing and recording apparatus. This method is based upon the reaction of bromine with sulfur-containing compounds such as hydrogen sulfide, sulfur dioxide, mercaptans, organic sulfides, and disulfides. The concentration of bromine in the apparatus is kept constant by the electrolytic generation of bromine. Thus, any reactive material in the gas will lower the bromine concentration causing the bromine generator to increase. The recorder automatically records the changes in the generating current. It is possible to distinguish the different types of sulfur compounds by passing the gas through suitable chemical filters, thus removing certain classes of sulfur compounds. This apparatus is commercially available, under the name *Titrilog*, and manufactured by Consolidated Engineering Corporation, Inc., Pasadena, California.

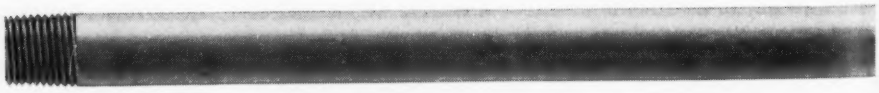
Probably the cheapest and most convenient method of accurately checking gas odors is to use an odorometer. Odorometers have the advantage that they are portable and may be used to measure the odor intensity of gas in the field. Most odorometers operate by mixing the gas and air with an electric blower and determining the gas concentration by means of a flowmeter or combustible gas detector. The odor of the gas-air mixture is then measured by an odor panel. The first odorometer for field use was reported in 1950 by California Research Corporation, the research affiliate of Oronite Chemical Company. Since that time, the Oronite Odorometer has been improved and the current (fourth) model is being successfully used by many companies in the United States and Europe.

No patent application has been made on this instrument. Any utility desiring to build this unit or a modification of it is free to do so. Design information is available from Oronite Chemical Company. The odorometer was developed with the hope that it would help develop some standard means of determining the odor intensity level in natural gas. The fourth model is available commercially from Johnson-Williams Company of Palo Alto, California, makers of J-W Combustible Gas Indicators.

Similar types of odorometers incorporating different features of design are available from other manufacturers.

says
Capt. Sopholacledes,
Engineering Corps,
Royal Macedonian Army

"Heavy timber framing and supports took a lot of time and sweat to erect. A strong framework of Laclede Steel Pipe would have allowed 20 more G.I.'s (Greek Infantrymen) to stow away in this mahogany mare. And a couple of good stout lengths would've made dandy axles; those poor Trojans had a rough time dragging the nag inside the walls. With Laclede's help, taking Troy could've been a — er — steel pipe cinch."



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Handling of Odorants

Transfer and Handling of Odorants

The transfer of odorants from drums to the odorizer supply tank is best accomplished by means of special loaders which use gas pressure to transfer the odorant. These loaders, which are threaded to fit the bung of the odorant drum, have a standpipe running to the bottom of the drum. Pressure is admitted to the surface of the odorant inside the drum by means of a valve in the loader and the odorant is forced up through the standpipe into a line running to the odorizer. A safety valve should be incorporated in the loader to prevent excess pressures (5 to 7 psig) in the drum. After cutting out the head of the drum and eliminating any residual odorant by one of the methods described in the section below, the drums may be discarded without causing an odor problem. Hand cutters and loaders for drums are commercially available at reasonable cost.

Bulk transfer from tank cars or tank trucks to large storage tanks offers no disposal problems as in the case of drums. However, spillage that occurs during pumping or displaced vapor from the odorant storage tank will give odors that are troublesome. The same precautions used in handling or transferring gasoline should be observed when handling any gas odorant. The next section describes several methods that may be used to control these nuisance odors.

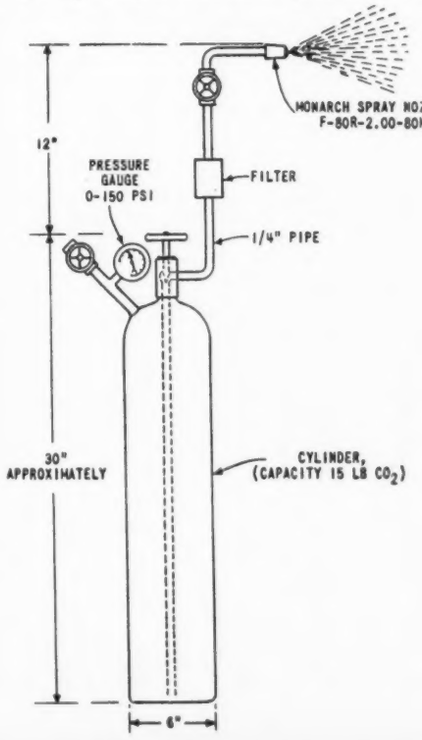
Methods of Controlling Nuisance Odors

Sources of Nuisance Odors. In operating gas odorizing equipment, odors are occasionally released into the atmosphere as a result of:

1. Opening and emptying odorant drums or tank trucks.
2. Venting, filling or blowing down storage tanks.
3. Disposing of empty odorant drums.
4. Leaks from an odorizer unit.
5. Leaks during replacement of odorizer parts.

Five methods of controlling nuisance odors have been found effective under certain conditions. These methods and their limitations are described in the following sections.

Adsorption Method. The common adsorbing agent, *activated carbon,* works best when the odor is present in a confined space such as in an odorizer building. In this case, the carbon is placed in trays and connected to a blower fan. The blower may keep a slight vacuum or pressure in the building, but in either case the air leaving the building must pass through the carbon. Vent lines of odorizers can also be equipped with carbon adsorbers.



Carbon will adsorb both mercaptan and sulfide odorants. However, mercaptans may generate so much heat that spontaneous combustion may occur. For this reason, it is not advisable to spread activated carbon directly over any odorant spills.

Combustion Method. This method is widely used, but is not convenient when the odorizer is located within ¼-mile of inhabited buildings. Generally, all the vent lines of the odorizer and filling equipment are connected by pipe to a burner. This burner is located a short distance from the odorizer and may be equipped with a pilot light. In the case of empty odorant drums, the heads are cut out and a small quantity of kerosine is ignited inside the drum. After combustion is complete, the drums may be disposed of in a normal manner.

Chemical Method. Oxidizing agents, such as hypochlorite solutions, have been widely used to reduce odors. This procedure, however, is sometimes unsatisfactory because it is only temporary in effect. Moreover, only mercaptan-type odorants react with oxidizing agents. The oxidation of mercaptans is slow, taking as long as an hour and the products (disulfides) have a somewhat unpleasant odor, although much less intense than the original odorant. However, this procedure is useful for mercaptan spills because it does cause a permanent reduction in odor intensity and because it reduces the amount of any masking agents(described below) that might be used.

Odor Masking Method. Odor masking is defined as the modification of a malodor to a non-objectionable odor by the addition of another odor (masking agent). In general, the masking agent is an essential oil with a pleasant odor and is applied as a dilute solution in kerosine or water.

These masking agents will modify the odors of both sulfides and mercaptans and generally are effective long enough to allow the original odor of the odorant to dissipate. Spills on soil, wood, fabric, or residual odors in empty drums are effectively masked in this manner. Masking agents are commercially available.

Odor Counteraction Method. Odor counteraction is defined as the reduction of the psychological intensity (as detected by the olfactory perceptors) of a malodor by adding another substance. In this case, the resulting effect is a reduction in total odor rather than a modification to a pleasant odor as in the case of odor masking.

Odor counteraction agents appear to be as effective toward the different types of odorants and spills as the odor masking agents described in this section. Odor counteraction agents that are effective with Oronite odorants are also commercially available.

A useful "fogging" apparatus for applying dilute solutions of odor masking and counteraction agents is shown in Fig. A. This apparatus is a 15-lb carbon dioxide cylinder modified with an oil fogging nozzle and a fitting for filling and pressurizing. About 1-gal of the dilute odor modifying solution is added and the cylinder pressurized with nitrogen gas to 60 psi. By opening the top valve, a fog may be produced continuously for approximately 30 minutes. On several occasions when actual spills of odorants have been "fogged" with this apparatus, no complaints were made by personnel in the vicinity of the spill.

Masking agents and counteraction agents are available by name from the following manufacturers: *Neutroleum, Alpha* and *Gamma* manufactured by Fritsche Brothers; *"Alamask"* manufactured by E. I. duPont Corporation, *"Wintair"* manufactured by Polak & Schwarz, Inc.

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PHYSICAL CONSTANTS OF HYDROCARBONS AND OTHER COMPOUNDS ASSOCIATED WITH NATURAL GAS

	Methane	Ethane	Propane	iso-butane	n-butane	iso-pentane	n-pentane	n-hexane	n-heptane	Carbon dioxide	Nitrogen	Oxygen	Ar	Hydrogen sulphide	Water
Atomic formula	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_4H_{10}	C_5H_{12}	C_5H_{12}	C_6H_1	C_7H_{1c}	CO_2	N_2	O_2	.....	H_2S	H_2O
Molecular weight	16.042	30.068	44.094	58.120	58.120	72.146	72.146	86.172	100.198	44.01	28.016	32.000	28.966	34.076	18.016
Boiling point—760 mm. °F	—258.5	—128.2	—43.8	+10.0	+31.1	+82.3	+97.0	+155.7	+209 1	—109.3	—320.4	—297 4	.....	—76 5	212
°C	—161.4	—89.0	—42.1	—12.2	—0.5	+27.9	+36 1	+68.7	+98.4	—78.5	—195.8	—183 0	.....	—60.3	100
Melting point—760 mm. °F	—296.5	—297.8	—305.8	—229.0	—218.2	—257.1	—201.5	—139.9	—131.4	*	—345.6	—361.1	.....	—121.9	+32
°C	—182.5	—183.2	—187.7	—145.0	—139.0	—160.6	—129.7	—95.5	—90.8	*	—209.8	—218.4	.....	—85 5	0.0
Critical temperature °R	343.1	549.7	665.8	732.8	765.2	829.6	846.5	914.2	972.2	547.6	226.8	277 7	238.3	672.3	1165.0
°K	190.6	305.4	369.9	407.1	425.1	460.9	470.3	507.9	540.1	304.2	126 0	154.3	132.4	373.5	647.2
°F	—116.5	+90.1	206.2	273.2	305.6	370.0	387.0	454.6	512.6	88.0	—232 8	—181.8	—221 3	+212.7	+705.4
°C	—82.5	+32.3	96.8	134.0	152.0	187 8	197.2	234 8	267.0	31.1	—147.1	—118.8	—140 7	+100 4	+374.1
Critical pressure															
Atmospheres	45.8	48.2	42.0	35.2	37.5	32.8	33.0	29.5	27.0	73.0	33.5	49.7	37.2	88.9	218.2
Lb per sq. in abs	673	708	617	517	551	482	485	434	397	1073	492	730	547	1306	3206.2
Critical volume															
Ml per gm. mol	99.0	148.0	195.0	249.0	258.0	307.6	310.9	367.2	427.0	95.6	90.1	74.4	93.4	.....	56.6
Cu. ft. per lb mol	1.586	2.371	3.123	3.990	4.130	4.930	4.98	5.88	6 84	1.532	1.443	1 192	1.496	.....	0.906
Critical density lb. per gal	1.351	1.695	1.888	1.946	1.891	1.955	1.935	1.958	1.957	3.839	2.596	3.589	2.588	.....	2.658
Liquid density data															
Specific gravity															
60°/60°F	0.3	0.4	0.509	0.564	0.584	0.625	0.631	0.664	0.688	.....	.....	.....	.....	0.79	1.000
°A.P.I. at 60°F	340.0	222.0	146 5	119.4	110.8	94.9	92.7	81.6	74.2	.....	.....	.....	.....	47.6	10.0
Density, lb. per gal. at 60°F (wt. in air)	2.5	3.3	4.23	4.69	4.86	5.20	5.25	5.53	5.73	.....	.....	.....	.....	6.58	8.327
Vapor density data (760 mm., 60°F															
Specific gravity (perfect gas) (air = 1.00)	0.554	1.038	1.522	2.006	2.006	2.491	2.491	2.975	3.459	1.519	0.967	1.105	1.000	1.176	0.622
Density (perfect gas)															
Cu. ft per lb.**	23.66	12.62	8.61	6.53	6.53	5.26	5.26	4.40	3.79	8.62	13.54	11.86	13 10	11.14	21.06
Lb per 1000 cu ft.***	42.27	79 23	116.2	153.2	153.2	190.1	190.1	227 1	264.0	116.0	73 83	84 32	76.33	89 80	47 48
Cu ft. vapor per gal. liquid (perfect gas)**	59.17	42.09	36.52	30.70	31.79	27.41	27.67	24.38	21.72	.....	.....	.....	.....	73.35	175.62
Gal. liquid per 1000 cu. ft. vap. (perfect gas)***	16.90	23.76	27.38	32.57	31.45	36.48	36.14	41.02	46.03	.....	.....	.....	.....	13.63	5.69
Ratio gas volume per liquid volume (perfect gas)	442.6	314.8	273.2	229.7	237.8	205.0	207.0	182.4	162.5	.....	.....	.....	.....	548.7	1313.7
Deviation factor—(760 mm. 60°F.)	1.0020	1.008	1.016	1.030	1.032	1.045	1.048	1.066	1.087	1.0058	1.00030	1.00075	1.00039	1.011	1.0012
															13.25 mm.
100°F	1.0015	1.007	1.013	1.025	1.027	1.040	1.043	1.056	1.071	1.0047	1.00012	1.00052	1.00020	.....	1 0026
															49.1 mm.
Gross heat of combustion															
B.t.u. per lb vapor	23.916	22.350	21.692	21.288	21.338	21.058	21.121	20.970	20.859	.....	.....	.....	.....	7.479	.....
B.t.u. per cu. ft (perfect gas) 30-in.—60°F (dry)****	1013	1775	2526	3268	3276	4012	4025	4773	5521	.....	.....	.....	.....	673	.....
Specific heat. B.t.u. per lb. (760 mm., 60°F.)															
Cp	0.530	0.415	0.376	0.357	0.357	.....	0.347	0.339	0.335	0.199	0.248	0.218	0.241	0.254	0.458
Cv	0.405	0.346	0.324	0.312	0.312	0.309	0.309	0.305	0.302	0.153	0.176	0.155	0.171	0.192	0.343
Cp/Cv	1.309	1.198	1.161	1.144	1.144	1.121	1.121	1.113	1.109	1.304	1 404	1.401	1.410	1.32	1.335
Cp Liq	.....	.....	.....	.55 at 32	.55 at 32	.53	64	.536	.522	.....	.....	.....	.....	.....	1.000
Heat of fusion B.t.u. per lb.—760 mm.	25.2	40.9	34.4	.....	32.4	30.4	49.9	65.0	59.6	81.5	11.0	5.9	.....	30.0	143.4
Heat of vaporization at boiling point. B.t.u. per lb.—760 mm	249	210	183	157	165	150	151	143	137	.....	.....	.....	.....	236	971
Vapor pressure at 100°F., lb. per sq. in. abs.	.....	.....	189.5	73.5	52.0	20.3	15.5	5.0	1.63	.....	.....	.....	.....	554.6	0.949
Octane No., Motor Method. A S T M D 357-37T	100+	100+	99.5	97.0	90.5	88.7	69.3	59.0	0.0	.....	.....	.....	.....	.....	.....

*Sublimes.

**To convert to a basis of 14.73 lb. per sq. in. or 30 in. Hg multiply by 0.99769.

***To convert to a basis of 14.73 lb. per sq. in. or 30 in. Hg multiply by 1.00232.

****To convert to a basis of water saturation at 60°F. multiply by 0.9825.

Note: Except where otherwise indicated, values are expressed on an "Actual" gas basis.

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Density (lb per cu ft) of 0.60 Specific Gravity Gas (Air = 1)

Pressure	Temperature, deg. fahr.									
	20	30	40	50	60	70	80	90	100	110
25 in. Hg. vac.	.00845	.00827	.00811	.00795	.00780	.00765	.00751	.00737	.00724	.00711
20	.01669	.01635	.01602	.01571	.01541	.01511	.01483	.01456	.01430	.01405
15	.02496	.02445	.02397	.02350	.02305	.02261	.02219	.02179	02140	.02102
10	03324	.03256	.03191	.03128	.03069	.03010	02955	.02901	02849	.02799
5	.04148	.04064	.03982	.03904	.03830	.03757	.03687	.03620	03555	.03493
Atmos.	.04976	.04874	.04777	.04683	.04593	.04506	.04423	.04342	.04265	.04190
5 lb./in². gauge	.06665	.06529	.06398	.06273	.06154	.06036	.05924	.05816	05712	.05612
10	.08354	.08184	.08020	.07862	.07714	.07566	.07425	.07290	07160	.07034
15	.10043	.09838	.09641	.09452	.09273	.09095	.08927	08764	08608	08456
20	.11732	.11493	.11263	.11042	.10833	.10625	.10428	.10238	10055	.09879
25	.13422	.13148	.12884	.12631	.12392	.12154	.11929	.11712	.11503	.11301
30	15111	.14802	.14506	.14221	.13952	.13684	.13431	.13186	12950	12723
35	.16800	.16457	.16127	.15811	.15511	.15214	.14932	.14660	14398	14145
40	.18489	.18111	.17749	.17400	.17071	.16743	16433	.16134	15846	.15567
45	20178	.19766	.19370	.18990	.18631	.18273	.17934	.17608	17293	.16990
50	.21867	.21420	.20992	.20580	.20190	.19803	.19436	.19082	18741	.18412
60	.25245	.24730	.24235	.23759	.23309	.22862	.22438	.22030	21636	.21256
70	28623	.28039	.27478	.26938	.26428	.25921	.25441	.24978	24531	.24101
80	.32002	.31348	.30720	.30118	.29547	.28980	.28443	.27926	27427	.26945
90	.35380	.34657	.33963	.33297	.32667	32040	.31446	.30874	30322	.29790
100	.38758	.37966	.37206	.36476	.35786	.35099	.34449	.33822	33217	.32634
125	.47203	.46239	.45314	.44425	.43584	.42747	.41955	.41191	.40455	.39745
150	.55649	.54512	.53421	.52373	.51381	.50395	.49461	.48561	.47693	.46856
175	.64094	.62785	.61529	.60321	.59179	.58043	.56968	.55931	.54932	.53967
200	.72540	.71058	.69636	.68269	.66977	.65692	.64474	.63301	62170	.61078
225	.80985	.79331	.77743	.76218	.74775	.73340	.71981	.70671	.69408	.68189
250	.89431	.87604	.85851	.84166	.82573	.80988	.79487	.78040	.76646	.75300
275	.97876	.95877	.93958	.92114	.90370	.88636	.86994	85410	.83884	82411
300	1.0632	1.0415	1.0207	1.0006	.98168	.96284	.94500	.9278	.91122	.89522
325	1.1477	1.1242	1.1017	1.0801	1.0597	1.0393	1.0201	1.0015	.98360	.96633
350	1.2321	1.2070	1.1828	1.1596	1.1376	1.1158	1.0951	1.0752	1.0560	1.0374
375	1.3166	1.2897	1.2639	1.2391	1.2156	1.1923	1.1702	1.1489	1.1284	1.1086
400	1.4010	1.3724	1.3449	1.3186	1.2936	1.2688	1.2453	1.2226	1.2007	1.1797
425	1.4855	1.4551	1.4260	1.3980	1.3716	1.3453	1.3203	1.2963	1.2731	1.2508
450	1.5699	1.5379	1.5071	1.4775	1.4496	1.4217	1.3954	1.3700	1.3455	1.3219
475	1.6544	1.6206	1.5882	1.5570	1.5275	1.4982	1.4705	1.4437	1.4179	1.3930
500	1.7389	1.7033	1.6692	1.6365	1.6055	1.5747	1.5455	1.5174	1.4903	1.4641
600	2.0767	2.0343	1.9935	1.9544	1.9174	1.8806	1.8458	1.8122	1.7798	1.7485
700	2.4145	2.3652	2.3178	2.2724	2.2293	2.1865	2.1460	2.1070	2.0693	2.0330
800	2.7523	2.6961	2.6421	2.5903	2.5412	2.4925	2.4463	2.4018	2 3588	2.3174
900	3.0901	3.0270	2.9664	2.9082	2.8532	2.7984	2.7465	2.6966	2.6484	2.6019
1000	3.4279	3.3579	3.2907	3.2261	3.1651	3.1043	3.0468	2.9914	2.9379	2.8863
1100	3.7658	3.6889	3.6150	3.5441	3.4770	3.4103	3.3471	3.2861	3.2274	3.1708
1200	4.1036	4.0198	3.9393	3.8620	3.7889	3.7162	3.6473	3.5809	3.5169	3.4552
1300	4.4414	4.3507	4.2636	4.1799	4.1008	4.0221	3.9476	3.8757	3.8065	3.7396
1400	4.7792	4.6816	4.5879	4.4979	4.4127	4.3280	4.2478	4.1705	4.0960	4.0241
1500	5.1170	5.0125	4.9122	4.8158	4.7246	4.6340	4.5481	4.4653	4.3855	4.3085
1750	5 9616	5.8398	5.7229	5.6106	5.5044	5.3988	5.2987	5.2023	5.1093	5.0196
2000	6.8061	6.6671	6.5337	6.4055	6.2842	6.1636	6.0494	5.9393	5.8331	5.7307
2250	7.6507	7.4944	7.3444	7.2003	7.0640	6.9284	6.8000	6.6763	6.5570	6.4418
2500	8.4952	8.3217	8.1552	7.9951	7.8438	7.6932	7.5507	7.4132	7.2808	7.1529
2750	9.3398	9.1490	8.9659	8.7899	8.6235	8.4580	8.3013	8.1502	8.0046	7.8640
3000	10 1843	9.9763	9.7766	9.5848	9.4033	9.2229	9.0520	8.8872	8.7284	8.5751
3500	11 8734	11.6309	11.3981	11.1744	10 9629	10.7525	10.5533	10.3612	10.1760	9.9973
4000	13 5625	13.2855	13.0196	12 7641	12.5224	12.2821	12.0545	11 8351	11.6236	11 4196
4500	15 2516	14.9401	14.6411	14.3537	14 0820	13.8118	13 5558	13 3091	13.0713	12 8418
5000	16.9407	16.5947	16.2625	15.9434	15.6416	15.3414	15.0571	14.7831	14.5189	14.2640

VAPOR PRESSURES, POUNDS PER SQUARE INCH ABSOLUTE

Temperature, °F	Acetylene, C_2H_2	Ammonia, NH_3	Benzene, C_6H_6	n-Butane, C_4H_{10}	Isobutane, C_4H_{10}	Carbon Dioxide, CO_2	Carbon Disulfide, CS_2	Ethane, C_2H_6	Ethyl Alcohol, C_2H_5OH	Ethyl Chloride C_2H_5Cl	Hydrogen Sulfide, H_2S	Methyl Chloride, CH_3Cl	Naphthalene, $C_{10}H_8$		Propane, C_3H_8	Sulfur dioxide, SO_2	Toluene, C_7H_8	Water, H_2O	*m*-Xylene, C_8H_{10}
													Dry	Moist					
—20	162	18.30	....	....	7.50	215.02	0.53	158	0.022	2.16	57.5	11.75	....	....	25.4	5.883	....	....	....
—10	196	23.74	....	....	9.28	257.46	0.74	185	0.036	2.94	70.0	15.0	....	....	31.4	7.863	....	....	....
0	232	30.42	....	7.3	12.1	305.5	1.00	218	0.058	3.93	84.0	18.8	....	....	38.2	10.35	....	....	....
10	271	38.51	....	9.3	14.8	360.2	1.36	250	0.090	5.13	100	23.3	....	....	46.5	13.42	....	....	....
20	319	48.21	....	11.8	18.2	421.8	1.80	290	0.140	6.65	120	28.8	....	....	55.5	17.18	....	....	....
30	372	59.74	0.48	14.4	23.3	490.8	2.30	334	0.220	8.40	143	35.2	0.000096	0.000029	66.3	21.70	0.125	....	0.031
32	387	62.29	0.52	15.8	23.2	505.5	2.46	346	0.236	8.85	150	36.6	0.00011	0.000033	68.0	22.47	0.137	0.0887	0.034
40	430	73.32	0.66	18.4	26.9	567.8	2.96	381	0.330	10.53	169	42.6	0.00018	0.000057	78.0	27.10	0.176	0.1217	0.042
50	495	89.19	0.88	22.7	32.2	653.6	3.83	418	0.456	13.20	197	51.5	0.00034	0.00012	91.8	33.45	0.247	0.1780	0.061
60	565	107.6	1.14	27.1	38.7	748.6	4.75	496	0.640	16.5	230	61.6	0.00060	0.00026	107.1	40.93	0.335	0.2561	0.093
70	645	128.8	1.51	32.7	45.8	853.4	5.93	560	0.910	20.0	267	73.3	0.0011	0.00057	124.0	49.62	0.455	0.3628	0.131
80	735	153.0	1.95	39.0	53.9	968.7	7.30	632	1.25	24.3	302	85.3	0.0013	0.0013	142.8	59.68	0.607	0.5067	0.178
90	830	180.6	2.51	46.2	63.3	....	9.00	708	1.71	29.0	344	102.1	0.0032	0.0029	164.0	71.25	0.790	0.6980	0.241
100	..	211.9	3.20	55.0	74.7	....	10.8	...	2.32	34.9	392	118.8	0.0054	0.0054	187.0	84.52	1.03	0.9487	0.330
110	...	247.0	4.05	64.2	85.1	....	13.3	...	3.09	41.1	442	137.6	0.0088	0.0094	212.0	99.76	1.32	1.274	0.435
120	...	286.4	4.22	75	98.0	....	16.0	...	4.02	48.1	500	158.8	0.0142	0.016	240.0	120.9	1.70	1.692	0.570
130	...	329	6.41	87	112.0	....	19.0	...	5.27	56.3	560	173	0.0218	....	272	135.0	2.13	2.221	0.745
140	...	379	7.53	101	126.8	....	22.6	...	6.82	66.1	632	200	0.0322	....	....	157.8	2.70	2.887	0.978
150	...	435	9.2	115	....	....	26.5	...	8.65	76.0	700	223	0.0439	....	....	181	2.30	3.716	1.22
160	...	495	11.0	132	....	....	30.9	...	10.9	86.3	778	253	0.071	....	....	209	4.03	4.739	1.53
170	...	560	13.0	151	....	....	35.9	...	13.5	99.0	862	287	0.105	....	....	239	5.00	5.990	1.94
180	...	640	15.4	172	....	....	41.9	...	17.0	113	962	322	0.155	....	....	272	6.02	7.510	2.42
190	...	715	18.2	194	....	....	48.0	...	21.0	127	1050	360	0.217	....	....	309	7.3	9.336	2.98
200	...	800	21.7	219	....	....	55.2	...	25.5	142	1160	400	0.277	....	..	350	8.7	11.525	3.62
210	...	890	25.4	248	....	....	63.0	...	31.1	161	1280	445	0.347	....	....	399	10.3	14.123	4.42
220	...	990	....	....	....	....	71.5	..	37.8	180	....	495	0.419	....	....	449	....	17.188	5.30
230	...	1100	....	....	....	....	81.6	...	45.7	203	....	550	0.547	....	....	501	....	20.78	6.35
240	...	1210	....	....	....	....	91.8	...	54.5	230	....	605	0.68	....	....	561	....	24.97	7.55
250	...	1340	....	....	....	....	103	...	64.5	260	....	670	0.85	....	....	624	....	29.82	9.0
	d	d, h	b, d	b, c, f	c, f	d, e, f	d	d	d	d, f,	d	d, e	b, d,	b	c, f	d, f	a, d	g	d

[a] Gas Chemists Handbook, Third Edition, 1929.

[b] Gas Engineers' Handbook, First Edition, 1934.

[c] Handbook of Butane-Propane Gases, Second Edition, 1935.

[d] Handbook of Chemistry and Physics, Nineteenth Edition, 1934.

[e] *Heating and Ventilating*, September and October 1938.

[f] L. S. Marks, Mechanical Engineers' Handbook, Third Edition, 1930.

[g] J. H. Keenan, "Steam Tables and Mollier Diagram," 1930.

[h] U. S. Bur. of Standards, Circular No. 142, 1923.

Note: Over small temperature intervals the logarithm of the vapor pressure plotted against temperature is practically a straight line. For longer temperature intervals the plot against reciprocal of the absolute temperature should be used.

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WATER VAPOR IN SATURATED GAS

Per cent by volume, calculated from the gas laws

Temperature, °F.	Pressure, Pounds per Square Inch Absolute										
	50	100	150	200	250	300	350	400	500	600	700
40	0.244	0.122	0.081	0.061	0.049	0.041	0.035	0.030	0.024	0.020	0.017
50	0.356	0.178	0.119	0.089	0.071	0.059	0.051	0.055	0.036	0.030	0.025
60	0.512	0.256	0.171	0.128	0.102	0.085	0.073	0.064	0.051	0.043	0.037
70	0.726	0.363	0.242	0.181	0.145	0.121	0.104	0.091	0.073	0.061	0.052
80	1.014	0.507	0.338	0.253	0.203	0.169	0.145	0.127	0.101	0.084	0.072
90	1.396	0.698	0.465	0.349	0.279	0.233	0.199	0.174	0.140	0.116	0.100
100	1.898	0.949	0.633	0.474	0.380	0.316	0.271	0.237	0.190	0.158	0.136

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GALLONS OF WATER PER MILLION CUBIC FEET OF GAS

Pressure and temperature bases: 14.4 pounds per square inch and 60° F
Gas saturated with water vapor at indicated pressures and temperatures

Temperature, °F.	Pressure, Pounds per Square Inch Absolute										
	50	100	150	200	250	300	350	400	500	600	700
40	13.6	6.8	4.5	3.4	2.7	2.3	2.0	1.7	1.4	1.1	1.0
50	19.9	10.0	6.6	5.0	4.0	3.3	2.8	2.5	2.0	1.7	1.4
60	28.6	14.3	9.5	7.2	5.7	4.8	4.1	3.6	2.9	2.4	2.0
70	40.5	20.2	13.5	10.1	8.1	6.8	5.8	5.1	4.0	3.4	2.9
80	56.4	28.2	18.8	14.1	11.3	9.4	8.1	7.0	5.6	4.7	4.0
90	78.0	39.0	26.0	19.5	15.6	13.0	11.1	9.7	7.8	6.5	5.6
100	106.2	53.1	35.4	26.5	21.2	17.7	15.2	13.3	10.6	8.9	7.6

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VAPOR PRESSURE OF WATER

°F.	In. Hg	Lbs. per Sq. In. Absolute	°F.	In. Hg	Lbs. per Sq. In. Absolute	°F.	In. Hg	Lbs. per Sq. In. Absolute	°F.	In. Hg	Lbs. per Sq. In. Absolute
32	0.1803	0.08854	57	0.4686	0.2302	82	1.1016	0.5410	107	2.3786	1.1683
33	0.1878	0.09223	58	0.4858	0.2386	83	1.1378	0.5588	108	2.4491	1.2029
34	0.1955	0.09603	59	0.5035	0.2473	84	1.1750	0.5771	109	2.5214	1.2384
35	0.2035	0.09995	60	0.5218	0.2563	85	1.2133	0.5959	110	2.5955	1.2748
36	0.2118	0.10401	61	0.5407	0.2655	86	1.2527	0.6152	115	2.9948	1.4709
37	0.2203	0.10821	62	0.5601	0.2751	87	1.2931	0.6351	120	3.4458	1.6924
38	0.2292	0.11256	63	0.5802	0.2850	88	1.3347	0.6556	125	3.9539	1.9420
39	0.2383	0.11705	64	0.6009	0.2951	89	1.3775	0.6766	130	4.5251	2.2225
40	0.2478	0.12170	65	0.6222	0.3056	90	1.4215	0.6982	135	5.1653	2.5370
41	0.2576	0.12652	66	0.6442	0.3164	91	1.4667	0.7204	140	5.8812	2.8886
42	0.2677	0.13150	67	0.6669	0.3276	92	1.5131	0.7432	145	6.680	3.281
43	0.2782	0.13665	68	0.6903	0.3390	93	1.5608	0.7666	150	7.569	3.718
44	0.2891	0.14199	69	0.7144	0.3509	94	1.6097	0.7960	155	8.557	4.203
45	0.3004	0.14752	70	0.7392	0.3631	95	1.6600	0.8153	160	9.652	4.741
46	0.3120	0.15323	71	0.7648	0.3756	96	1.7117	0.8407	165	10.863	5.335
47	0.3240	0.15914	72	0.7912	0.3886	97	1.7647	0.8668	170	12.199	5.992
48	0.3364	0.16525	73	0.8183	0.4019	98	1.8192	0.8935	175	13.671	6.715
49	0.3493	0.17157	74	0.8462	0.4156	99	1.8751	0.9210	180	15.291	7.510
50	0.3626	0.17811	75	0.8750	0.4298	100	1.9325	0.9492	185	17.068	8.383
51	0.3764	0.18486	76	0.9046	0.4443	101	1.9915	0.9781	190	19.014	9.339
52	0.3906	0.19182	77	0.9352	0.4593	102	2.0519	1.0078	195	21.144	10.385
53	0.4052	0.19900	78	0.9666	0.4747	103	2.1138	1.0382	200	23.467	11.526
54	0.4203	0.20642	79	0.9989	0.4906	104	2.1775	1.0695	205	26.003	12.772
55	0.4359	0.2141	80	1.0321	0.5069	105	2.2429	1.1016	210	28.755	14.123
56	0.4520	0.2220	81	1.0664	0.5237	106	2.3099	1.1345	212	29.922	14.696

A special case of partial pressure is that due to vapor pressures of substances at or near their condensing conditions, especially when in the presence of some liquids. The kinetic theory has shown how separation of molecules will permit the evaporation of other gaseous molecules into the same space. All liquids exposed to an available space will partially change to vapor. The partial pressure of this vapor in the space above the liquid is given the name "vapor pressure." For each temperature of the liquid, there is a corresponding vapor pressure. When the vapor pressure equals the external pressure, the liquid is at its boiling point. For water under pressure of one atmosphere, 212° F is the temperature at which this phenomenon takes place.

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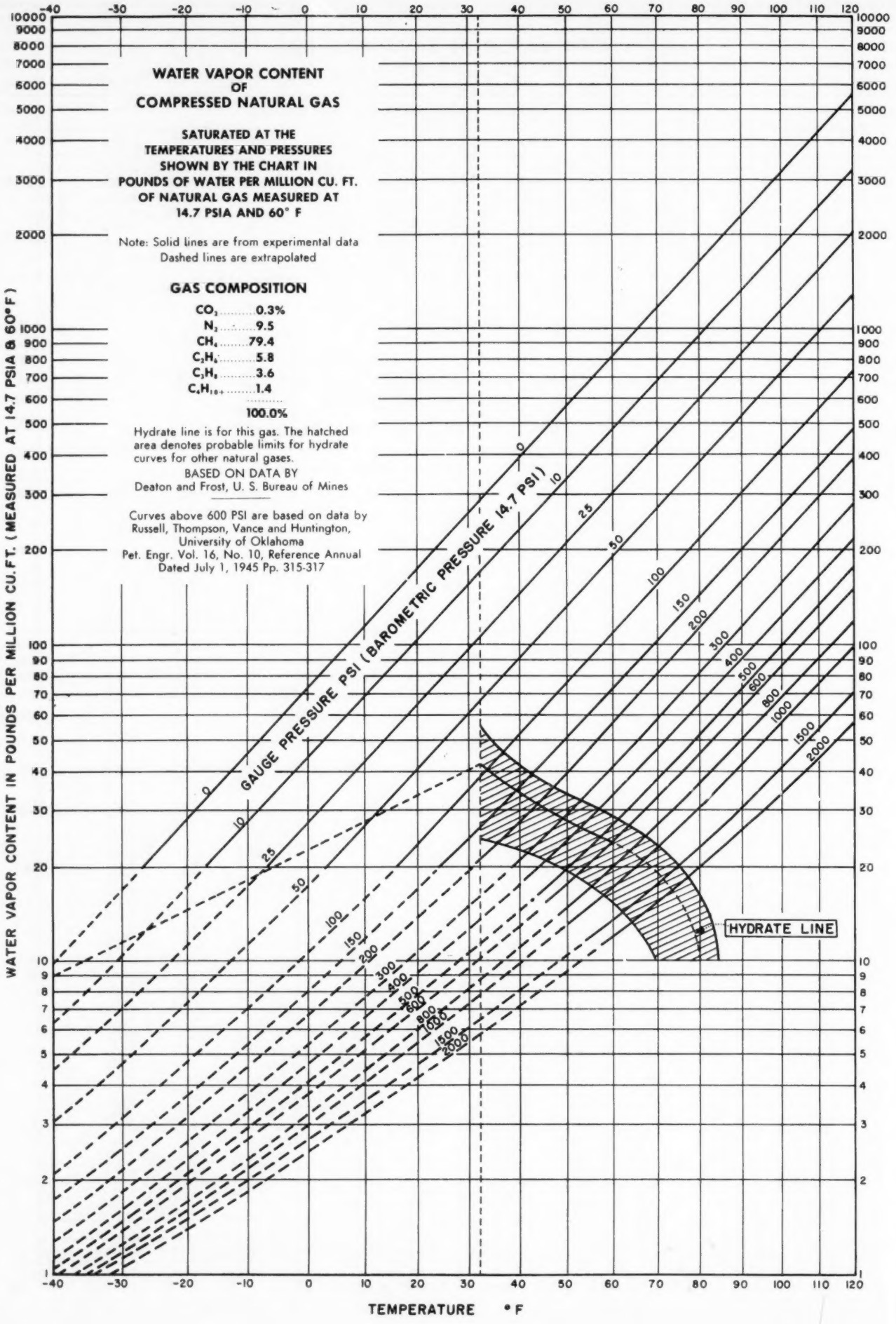

WATER VAPOR CONTENT
OF
COMPRESSED NATURAL GAS
SATURATED AT THE
TEMPERATURES AND PRESSURES
SHOWN BY THE CHART IN
POUNDS OF WATER PER MILLION CU. FT.
OF NATURAL GAS MEASURED AT
14.7 PSIA AND 60° F
Note: Solid lines are from experimental data
Dashed lines are extrapolated
GAS COMPOSITION
CO_2 ..... 0.3%
N_2 ..... 9.5
CH_4 ..... 79.4
C_2H_6 ..... 5.8
C_3H_8 ..... 3.6
C_4H_{10+} 1.4
100.0%
Hydrate line is for this gas. The hatched area denotes probable limits for hydrate curves for other natural gases.
BASED ON DATA BY
Deaton and Frost, U. S. Bureau of Mines
Curves above 600 PSI are based on data by Russell, Thompson, Vance and Huntington, University of Oklahoma
Pet. Engr. Vol. 16, No. 10, Reference Annual
Dated July 1, 1945 Pp. 315-317
GAUGE PRESSURE PSI (BAROMETRIC PRESSURE 14.7 PSI)
0
10
25
50
100
150
200
300
400
500
600
800
1000
1500
2000
HYDRATE LINE
WATER VAPOR CONTENT IN POUNDS PER MILLION CU.FT. (MEASURED AT 14.7 PSIA & 60°F)
TEMPERATURE °F

TANK FORMULAS

The following formulas have been selected to facilitate the rapid calculation of capacities of various types of storage tanks in gallons and barrels.

Uniform Notations:

B — Capacity of each dished head in United States gallons.

B_2 — Total capacity of both dished heads in United States gallons.

C_B — Total capacity of tank in barrels (of 42 United States gallons).

C_G — Total capacity of tank in United States gallons.

C_{GF} — Capacity of cylindrical portion of tank in United States gallons per foot length. (Flat heads.)

D — Inside diameter of tank in feet.

G — Liquid contents of partially filled tank in United States gallons.

L — Length of cylindrical portion of tank in feet.

b — Dish of head, bead line to inside of plate (height of arc) in inches.

d — Inside diameter of tank in inches.

h — Depth or height of liquid in tank in inches.

l — Length of cylindrical portion of tank in inches.

r — Radius of dished head (where different from tank diameter) in inches.

Capacity of Vertical Cylindrical Tanks with Flat Heads

R — Inside radius of tank in feet.

H — Height of liquid in feet.

Capacity in United States gallons, per foot depth

$C_{gf} = 23.501\ R^2$.

Total capacity in United States gallons

$C_g = 23.501\ R^2H$.

Total capacity in barrels (of 42 United States gallons)

$C_b = 0.56\ R^2H$.

Capacity of Horizontal Cylindrical Tanks with Flat Heads

Total capacity in United States gallons

$C_g = 0.0034\ d^2l$.

Total capacity in barrels (of 42 United States gallons)

$C_b = 0.14\ D^2L$.

Capacity of Horizontal Cylindrical Tanks with Dished Heads

(where radius of dished head equals diameter of tank)

Total capacity in United States gallons

$C_g = 0.0034\ d^2l + 0.0004664\ d^3$.

Total capacity in United States gallons

$C_g = 5.875\ D^2L + 0.806\ D^3$.

Total capacity in barrels (of 42 United States gallons)

$C_b = 0.14\ D^2L + 0.019\ D^3$.

Capacity of Dished Head of any Radius

Capacity of each dished head in United States gallons

$B = 0.0045333\ b^2\ (3r - b)$.

Capacity of Spherical Tanks

Total capacity in United States gallons

$C_g = 0.0022666\ d^3$.

Total capacity in United States gallons

$C_g = 3.9168\ D^3$.

Total capacity in barrels (of 42 United States gallons)

$C_b = 0.093257\ D^3$.

Liquid Contents of partially filled Tanks

Horizontal Cylindrical Tanks with Flat Heads:

Liquid contents in United States gallons.

$$G = \frac{1}{231}\left[0.004363\ d^2\ \text{Cos}^{-1}\frac{d-2h}{d} - \frac{d-2h}{2}\sqrt{h(d-h)}\right].$$

The notation $\text{Cos}^{-1}\ \frac{d-2h}{d}$ read inverse cosine of $\frac{d-2h}{d}$, or arc cosine $\frac{d-2h}{d}$ means the angle (in degrees) whose cosine is equal to $\frac{d-2h}{d}$.

The use of this inverse function can best be illustrated by an example:

Find the number of gallons contained in a horizontal cylindrical tank with flat heads, if the tank inside diameter is 100 inches, the length 50 inches, and the tank is filled with liquid to a depth of 10 inches. Substituting in the above formula,

$$G = \frac{50}{231}\left[0.004363(100)^2\text{Cos}^{-1}\ \frac{100-20}{100} - \frac{100-20}{2}\sqrt{10(100-10)}\right],$$

$$G = 0.21645\ [\,43.63\ \text{Cos}^{-1}\ 0.80 - 40\sqrt{900}\,].$$

But, as stated above, Cos^{-1} 0.80 means "the angle of which the cosine is 0.80." From a table of natural cosines the angle is found to be 36° 52′ or 36.87°. Substituting this value for Cos^{-1} 0.80 we have,

$G = 0.21645\ (43.63 \times 36.87 - 1200)$,

$G = 0.21645 \times 408.6$,

$G = 88.45$ gallons.

Note: In calculating liquid contents of partially filled tanks, use formula for tanks up to half full. For tanks over half full, calculate capacity of unfilled portion and subtract from capacity of full tank.

Spherical Tanks:

G = Liquid contents in United States gallons

$= 0.0022666h^2(3d - 2h)$.

VAPORIZATION OF LIQUID IN PROPANE TANKS

Many times the question arises, especially on peak shaving installations using propane: Is it necessary to turn on the vaporizers?

For comparatively short-time peak shaving it is possible to obtain sufficient vapor from the storage tank itself without passing liquid propane through the vaporizer.

It is a well-known fact that the vapor pressure of a gas bears a direct relationship to the temperature and that the latent heat of vaporization is the amount of heat required to convert a liquid to a gas (also known as boiling point) at given pressure and temperature conditions; and further:

"The rate of heat transfer has been set at 2 Btu per hour per degrees temperature differential per sq. ft. of tank area in contact with the liquid."

Knowing these basic gas laws, we can evolve a formula to determine the amount of liquid propane vaporized in a standard storage tank in one hour.

$$\frac{2 \text{ Btu} \times (T_1 - T_2) \times \text{wetted area in sq ft}}{\text{LH per gal}} = \text{Gal/hr}$$

T_1 = Outside air temperature in degrees F

T_2 = Ultimate temperature in degrees F of propane liquid at minimum required pressure condition

LH: per gal = Latent Heat of vaporization (in Btu's) to vaporize one gallon of propane at T_2

As an example, let us assume that a 30,000 (wc) tank is half full of propane (wetted area = 1014 sq. ft.) and the outside air temperature is 80 F and the required vapor pressure can be as low as 10 psi gauge. How many gallons per hour is available due to the vaporization of liquid in storage tank?

Referring to standard table of thermodynamic properties of propane; temperature at 10 psi ga is —20 F; and the latent heat of vaporization is 750 Btu per gal.

From the above formula —

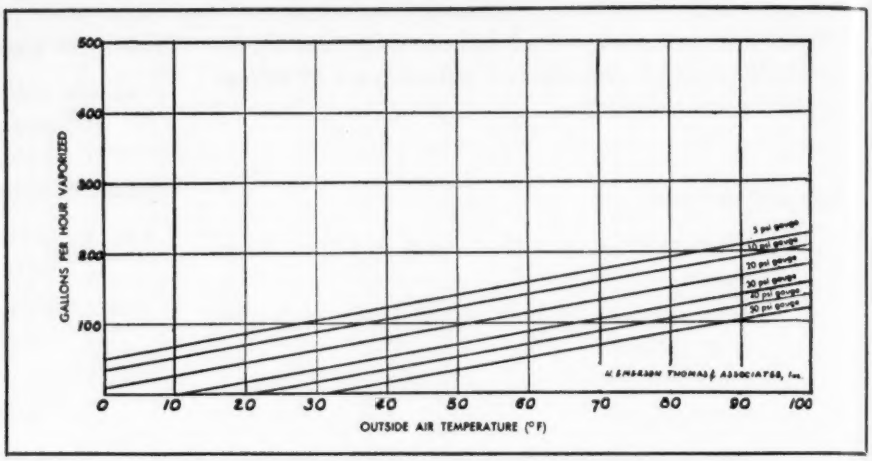
$$\frac{2 \text{ Btu} \times (80°\text{F} - 20°\text{F}) \times 1014 \text{ sq ft}}{750 \text{ Btu per gal}} = 271 \text{ gal}$$

With the above conditions, we therefore can vaporize 271 gallons per hour without recourse to a vaporizer.

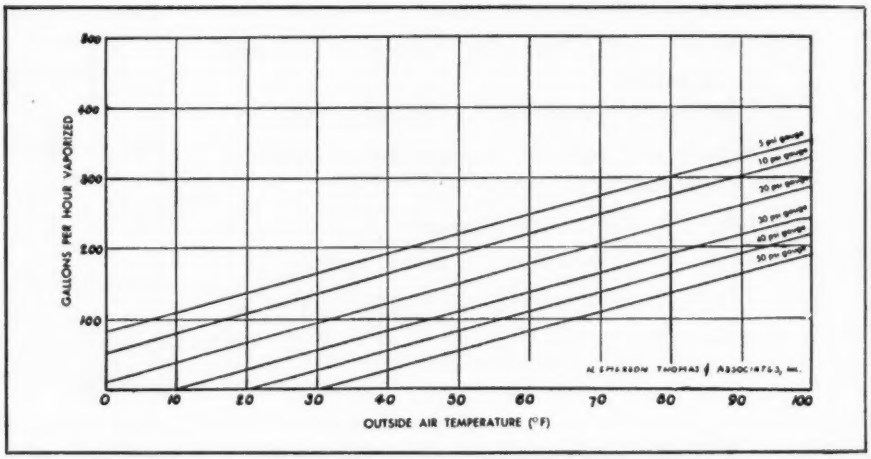
If this draw is maintained over a long period of time on a humid day, the surface of the tank in contact with the liquid will become frosted due to the refrigeration action of the liquid vaporized and the effective temperature differential will be substantially reduced. But in this discussion we are considering only comparatively short usages so as to obtain maximum vaporization.

Using the basic formula, graphs have been plotted which give available gallons per hour vaporized at various outside temperatures and pressure requirements of vapor and at varying filling heights in a 30,000 gallon (wc) tank containing commercial grade propane.

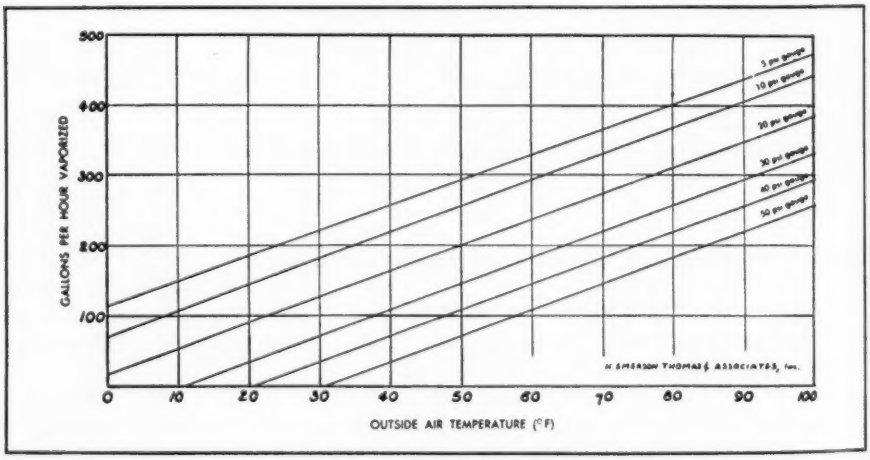
Referring to the graphs it is possible to decide when the vaporizer equipment will be required to obtain the necessary gas load.



Vaporization in 30,000 gallon tank, ¼ full—662 sq ft.



Vaporization in 30,000 gallon tank, ½ full—1014 sq ft.



Vaporization in 30,000 gallon tank, ¾ full—1365 sq ft.

Art E. Wastie, chief engineer, H. Emerson Thomas and Associates, Westfield, N. J.

Vapor Pressure of Propane, Butane and Isobutane

Temp. Deg F	Propane Pressure—lb per sq in. Absolute	Propane Gage	Butane Absolute	Butane Gage	Isobutane Absolute	Isobutane Gage	Temp. Deg F
−75	6.37	*17.0	—	—	—	—	−75
−70	7.37	*14.9	—	—	—	—	−70
−65	8.48	*12.7	—	—	—	—	−65
−60	9.72	*10.1	—	—	—	—	−60
−55	11.1	* 7.3	—	—	—	—	−55
−50	12.6	* 4.3	—	—	—	—	−50
−45	14.4	* 0.6	—	—	—	—	−45
−40	16.2	1.5	—	—	—	—	−40
−35	18.1	3.4	—	—	—	—	−35
−30	20.3	5.6	—	—	—	—	−30
−25	22.7	8.0	—	—	—	—	−25
−20	25.4	10.7	—	—	7.50	*14.6	−20
−15	28.3	13.6	—	—	8.30	*13.0	−15
−10	31.4	16.7	—	—	9.28	*11.0	−10
− 5	34.7	20.0	—	—	10.4	* 8.8	− 5
0	38.2	23.5	7.3	*15.0	11.6	* 6.3	0
5	41.9	27.2	8.2	*13.2	13.1	* 3.3	5
10	46.0	31.3	9.2	*11.1	14.6	* 0.2	10
15	50.6	35.9	10.4	* 8.8	16.3	1.6	15
20	55.5	40.8	11.6	* 6.3	18.2	3.5	20
25	60.9	46.2	13.0	* 3.6	20.2	5.5	25
30	66.3	51.6	14.4	* 0.6	22.3	7.6	30
35	72.0	57.3	16.0	1.3	24.6	9.9	35
40	78.0	63.3	17.7	3.0	26.9	12.2	40
45	84.6	69.9	19.6	4.9	29.5	14.8	45
50	91.8	77.1	21.6	6.9	32.5	17.8	50
55	99.3	84.6	23.8	9.1	35.5	20.8	55
60	107.1	92.4	26.3	11.6	38.7	24.0	60
65	115.4	100.7	28.9	14.2	42.2	27.5	65
70	124.0	109.3	31.6	16.9	45.8	31.1	70
75	133.2	118.5	34.5	19.8	49.7	35.0	75
80	142.8	128.1	37.6	22.9	53.9	39.2	80
85	153.1	138.4	40.9	26.2	58.6	43.9	85
90	164.0	149.0	44.5	29.8	63.3	48.6	90
95	175.0	160.0	48.2	33.5	68.4	53.7	95
100	187.0	172.0	52.2	37.5	73.7	59.0	100
105	200.0	185.0	56.4	41.7	79.3	64.6	105
110	212.0	197.0	60.8	46.1	85.1	70.4	110
115	226.0	211.0	65.6	50.9	91.4	76.7	115
120	240.0	225.0	70.8	56.1	98.0	83.3	120
125	254.0	239.0	76.0	61.3	104.8	90.1	125
130	272.0	257.3	81.4	66.7	112.0	97.3	130
135	288.0	273.3	87.0	72.3	119.3	104.6	135
140	305.0	290.3	92.6	77.9	126.8	112.1	140
145	—	—	100.0	85.3	136.0	121.3	145
150	—	—	108.0	93.7	145.0	130.3	150
155	—	—	115.0	100.3	155.0	140.3	155
160	—	—	122.0	107.3	165.0	150.3	160
165	—	—	130.0	115.3	175.0	160.3	165
170	—	—	140.0	125.3	186.0	171.3	170
175	—	—	150.0	135.3	198.0	183.0	175
180	—	—	160.0	145.3	210.0	195.3	180

* Inches of mercury below one standard atmosphere (29.92 in.).

Dana, Jenkins, Burdick and Timm, Refrigerating Engineering, June 1926.

Average Properties of Liquefied Petroleum Gas Products

	Commercial Propane	Industrial Propane	Commercial Butane
Vapor pressure lb/sq in. gage			
at 70 F	124	122	31
at 100 F	192	190	59
at 105 F	206	204	65
at 130 F	286	282	97
Specific gravity of liquid (60/60 F)	0.509	0.511	0.582
Initial boiling point at 14.7 lb/sq in. abs., F	−51	−51	15
Weight per gallon of liquid at 60 F, lb	4.24	4.26	4.84
Dew point at 14.7 lb/sq in. abs., F	−46	−45	24
Specific heat of liquid, btu/lb F at 60 F	0.588	0.587	0.549
Cu ft of gas at 60 F, 30 in. Hg. per gallon of liquid at 60 F	36.28	36.18	31.46
Specific volume of gas, cu ft/lb at 60 F, 30 in. Hg	8.55	8.50	6.50
Specific heat of gas, btu/lb/F at 60 F, (Cp)	0.404	0.401	0.382
Specific gravity of gas (Air=1) at 60 F., 30 in. Hg	1.52	1.53	2.01
Ignition temperature in air, F	920–1020	920–1020	900–1000
Maximum flame temperature in air, F	3595	3600	3615
Percent gas in air for maximum flame temperature, %	4.2–4.5	4.2–4.4	3.3–3.4
Maximum rate of flame propagation in 25 mm tube:			
Cms. per second	84.9	85.9	87.1
Inches per second	33.4	33.8	34.3
Limits of inflammability in air, gas percent in gas-air mixture:			
At lower limit, %	2.4	2.4	1.9
At maximum rate of flame propagation, %	4.7–5.0	4.7–4.9	3.7–3.9
At upper limit, %	9.6	9.6	8.6
Required for complete combustion:			
Cu ft O_2/cu ft gas	4.9	4.9	6.3
Cu ft air/cu ft gas	23.4	23.4	30.0
Lb O_2/lb gas	3.60	3.59	3.54
Lb air/lb gas	15.58	15.52	15.3
Products of complete combustion:			
Cu ft CO_2/cu ft gas	3.0	3.0	3.9
Cu ft H_2O/cu ft gas	3.8	3.8	4.6
Cu ft N_2/cu ft gas	18.5	18.5	23.7
Lb CO_2/lb gas	3.0	3.0	3.1
Lb H_2O/lb gas	1.6	1.5	1.5
Lb N_2/lb gas	12.0	11.9	11.8
Ultimate CO_2, % by volume	13.9	13.9	14.1
Latent heat of vaporization at boiling point:			
Btu per pound	185	184	167
Btu per gallon	785	784	808
Total heating values (after vaporization):			
Btu per cubic foot	2522	2537	3261
Btu per pound	21560	21570	21180
Btu per gallon	91500	91800	102600

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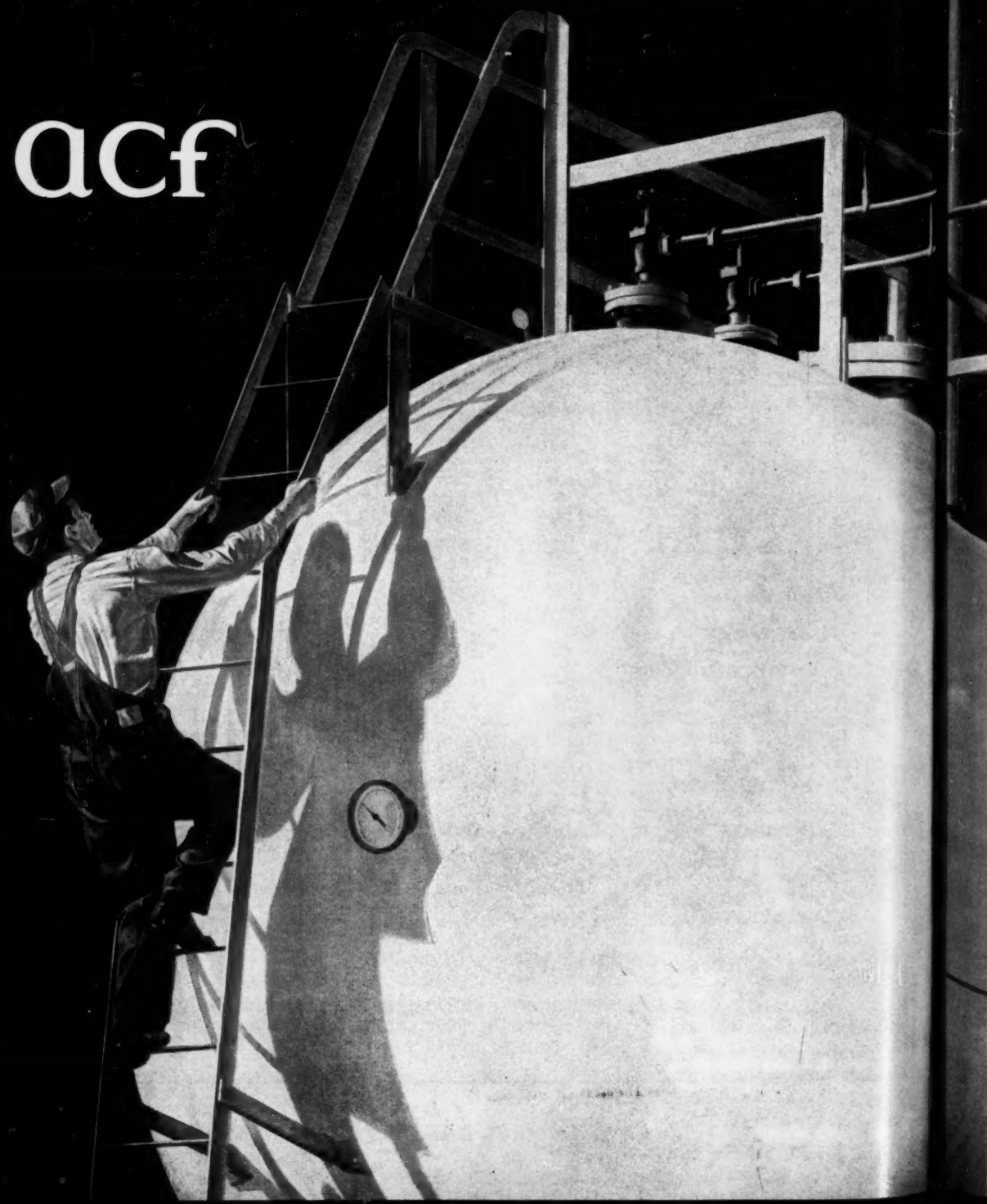

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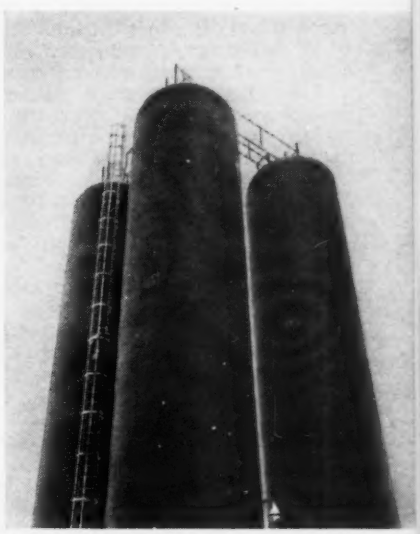

Vertical LPG Storage Tank

STANDARDS FOR

Storage and Handling of LPG at Utility Gas Plants

Introduction

This standard recommends basic requirements. The principal purpose of this standard is to outline methods for protection of persons and property by providing in a condensed form a standard of reference to serve as a guide to all persons concerned with the construction and operation of liquefied petroleum gas equipment at utility gas plants.

The term "liquefied petroleum gases" (LPG)* as used in this standard shall mean and include any material which is composed predominantly of any of the following hydrocarbons, or mixtures of them: propane, propylene, butanes, (normal butane or isobutane), and butylenes.

In the interest of safety, it is important that persons engaged in handling LPG understand the properties of the gases and that they be thoroughly trained in safe practices for the handling and distribution of these products.

Under moderate pressure the gases liquefy, but upon relief of the pressure readily change into a gas. Advantage of this characteristic is taken by the industry, and the gases are shipped and stored under pressure as liquids. The escape of liquid into the atmosphere normally results in instantaneous vaporization, with the volume of gases being between 200 and 300 times the volume of escaping liquid. When in the gaseous state these gases are heavier than air and have a lower limit of combustibility than natural or manufactured gas.

In the case of pure product at atmospheric pressure and below 31 F, normal butane is a liquid. Propane is a liquid at atmospheric pressure at temperatures below minus 44 F and normally does not present a flammable liquid hazard.

Commercially available butane and propane may have different liquefying points from those given above because they normally contain various percentages of other hydrocarbon products.

Section 1: General Requirements

11. Application of Rules

110. The following standards are intended to apply to utility gas companies for the design, construction, location, installation, and operation of LPG systems.

111. When operations involving container charging or transportation of LPG in liquid form are carried out on the same property, these operations shall conform to Standard for the Storage and Handling of Liquefied Petroleum Gases (No. 58).

112. Installations having an aggregate water capacity not exceeding 2000 gal shall conform to Standard for the Storage and Handling of Liquefied Petroleum Gases (No. 58).

113. LPG refrigerated storage systems are not covered by this standard.

114. When reference is made to gas in this standard it shall refer to LPG in either the liquid or gaseous state.

115. The term "containers" includes all vessels such as tanks, cylinders or drums used for storing LPG.

116. The term "systems" as used in this standard refers to an assembly of equipment consisting essentially of LPG unloading equipment, container or containers, major devices such as vaporizers, relief valves, excess flow valves, regulators, etc., and interconnecting piping. Such systems shall include any unloading equipment, storage equipment or interconnecting piping up to the outlet of the first stage regulator, vaporizer or mixing device, whichever is the last unit before the LPG enters other plant equipment or distribution lines.

117. The designation of containers used for storing any of the LPG defined in this standard shall depend on the type of construction employed during its fabrication.

(a) Containers completely fabricated within a plant under shop controlled conditions shall be known as "shop fabricated containers."

(b) Containers fabricated in whole or in part at or near their final location shall be known as "field erected containers."

118. The term "buried" refers to installations in which the top of the container (excluding the manway) is below the surrounding grade. The term "partially buried" (or mounded) refers to installations in which the top of the container is above the surrounding grade.

119. The abbreviations "psig" and "psia" as used in this standard refer to pounds per square inch gage and pounds per square inch absolute, respectively.

*EDITOR'S NOTE: The abbreviation LPG is used in this extract for brevity and should be construed to mean in all cases "liquefied petroleum gases" as defined in the paragraph hereby footnoted.

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12. Odorizing Gases.

120. All LPG shall be effectively odorized by an approved agent of such character as to indicate positively, by a distinctive odor, the presence of gas down to concentration in air of not over one-fifth the lower limit of combustibility; provided, however, that odorization is not required if harmful in the use or further processing of the LPG, or if odorization will serve no useful purpose as a warning agent in such use or further processing.

NOTE: The lower limits of combustibility of the more commonly used liquefied petroleum gases are: Propane, approximately 2 percent; Butane, approximately 1½ percent. These figures represent volumetric percentages of gas in a gas-air mixture in each case.

13. Testing and Listing of Equipment.

130. In systems utilizing containers of over 2000-gal water capacity, each container valve, excess flow valve, gaging device, relief device directly connected on the LPG container and direct fired vaporizer shall have its correctness as to design, construction, and performance determined by:

(a) Testing and Listing by Underwriters' Laboratories, Inc., or
(b) Testing and Listing by a nationally recognized agency for liquefied gas use, or
(c) The authority having jurisdiction.

14. Damage from Vehicles.

140. Where damage to LPG systems from vehicular traffic is a possibility, precautions against such damage shall be taken.

15. Electrical Equipment.

150. Electrical installations and equipment shall conform to the provisions of the National Electrical Code (No. 70) or be such as may be required and approved by the authority having jurisdiction.

151. Adequate lighting shall be provided to illuminate operating facilities such as walkways and essential control valves.

16. Sources of Ignition.

160. Open flames and other sources of ignition shall not be permitted in varporizer houses, gas mixing rooms and similar locations except direct fired vaporizers shall be located outside or in a separate room or building.

Section 2: Containers

21. Requirement for Construction and Original Test of Containers.

210. Containers shall be designed, constructed and tested in accordance with the Unfired Pressure Vessel Code sponsored by either the American Society of Mechanical Engineers (ASME) or the American Petroleum Institute and the American Society of Mechanical Engineers (API-ASME) or in accordance with the rules of the authority under which the containers are installed, provided such rules conform with the rules of the ASME Code or the API-ASME Code. (See Paragraph 412.)

(a) Containers constructed according to the 1949 and earlier editions of the ASME Code need not comply with the paragraphs U-2 to U-10 inclusive and U-19. Containers constructed according to paragraph U-70 are not authorized.

(b) Containers constructed according to API-ASME Code need not comply with the Section I or with appendix to Section I of said Code. Paragraphs W-601 to W-606 inclusive in the 1943 and earlier editions of said Code do not apply.

211. The provisions of Paragraph 210 shall not be construed as prohibiting the continued use or reinstallation of containers constructed and maintained in accordance with the Standard for the Storage and Handling of Liquefied Petroleum Gases (No. 58), in effect at the time of fabrication.

23. Design Working Pressure and Classification of Storage Containers.

230. Shop fabricated containers shall be designed and classified as shown in Table A (see next page).

231. Field erected containers shall be built in accordance with applicable provisions of the 1950 and later editions of the ASME Boiler and Pressure Vessel Code, Section VIII except construction under paragraphs UW-52(b) and (e) is not permitted.

References

The reader using information in this extract from NFPA Standard No. 59 should also refer to the following standards:

a. National Fire Protection Association, Standard No. 58, Storage and Handling of Liquefied Petroleum Gases, June 1959.
b. National Fire Protection Association, Standard No. 59, Storage and Handling of Liquefied Petroleum Gases at Utility Gas Plants, May 1958.
c. National Bureau of Fire Underwriters, Standards 58 and 30.
d. Fire codes, Volumes I and V.
e. API-ASME Code for Unfired Pressure Vessels for Petroleum Liquids and Gases (1951 edition with 1954 Addenda).
f. Rules for Construction of Unfired Pressure Vessels, Section VIII, ASME Boiler and Pressure Vessel Codes (1959).

Table A
Shop Fabricated Containers.

Container type	For gases with vapor press. Not to exceed psig at 100 F	Minimum Design Working Pressure of Container psig: 1949 and earlier edition of ASME Code (Par. U-68, U-69)	Minimum Design Working Pressure of Container psig: 1949 edition of ASME Code (Par. U-200, U-201); 1950, 1952 and 1956 editions of ASME Code; all editions of API-ASME Code
80*	80*	80*	100*
100	100	100	125
125	125	125	156
150	150	150	187
175	175	175	219
200**	215	200	250

*New containers of the 80 type have not been authorized since December 31, 1947.

**Container type may be increased by increments of 25. The minimum design working pressure of containers shall be 100% of the container type designation when constructed under 1949 or earlier editions of the ASME Code (Par. U-68 and U-69). The minimum design working pressure of containers shall be 125% of the container type designation when constructed under: (1) the 1949 ASME Code (U-200 and U-201), (2) 1950, 1952 and 1956 editions of the ASME Code; and (3) all editions of the API-ASME Code.

NOTE: Because of low soil temperatures usually encountered, and the insulating effect of the earth, the average vapor pressure of products stored in underground containers will be materially lower than when stored aboveground. This reduction in actual operating pressure therefore provides a substantial corrosion allowance for these containers when installed underground.

232. Field erected containers shall be designed for a pressure not less than the maximum vapor pressure of the product at 100 F to be stored in the container, but in no case shall the container be designed for a pressure of 25 psig or less. (For containers of 25 psig or less refer to Flammable Liquids Code, No. 30.)

233. The shell or head thickness of any container shall not be less than 3/16-in.

24. Markings on Containers.

240. Each container shall be marked as specified in the following:

(a) With a marking identifying compliance with, and other markings required by the rules of the code under which the container is constructed; or with the stamp and other markings required by the National Board of Boiler & Pressure Vessel Inspectors.

Underground: Container and an accessible name plate.
Aboveground: Container.

(b) With notation as to whether system is designed for underground or aboveground installation.

Underground: Container and an accessible name plate.
Aboveground: Container.

(c) With the water capacity of the container in gallons, U. S. Standard.

Underground: Container and an accessible name plate.
Aboveground: Container.

(d) With the pressure in psi for which the container is designed.

Underground: Container and an accessible name plate.
Aboveground: Container.

(e) With the wording "This container shall not contain a product having a vapor pressure in excess of — psig at 100 F." (See Paragraphs 230 and 232.)

Underground and aboveground: A name plate or tag on filler connection.

(f) With the outside surface area in square feet.

Underground: Container and an accessible name plate.
Aboveground: Container.

(g) With marking indicating the maximum level to which the container may be filled with liquid at temperatures between 20 F and 130 F except on containers provided with fixed maximum level indicators. Markings shall be in increments of 20 F.

Aboveground and underground: System name plate or on liquid level gaging device.

25. Location of Containers.

250. Aboveground Containers.

(a) Containers shall be located outside of buildings.

(b) Containers shall be located in accordance with Table B (see above).

(c) When the installation consists of a container or containers with an aggregate water capacity in excess of 180,000 gal, they and their loading stations should be located 100 ft or more from buildings occupied for generation, compression or purification of manufactured gas, or from natural gas compressor buildings, or from outdoor installations essential to the maintenance of operation in such buildings, and should be 100 ft or more from aboveground storage of flammable liquids and from any buildings of such construction or occupancy which constitutes a material hazard of exposure to the containers in the event of fire or explosion in said buildings. If the container or containers are located closer than 50 ft to any such buildings or installations, then the latter shall be protected by walls adjacent to such storage containers or by other appropriate means against the entry of escaped LPG, or of drainage from the storage container area and its loading points, — all in such a manner as may be required and approved by the authority having jurisdiction.

(d) LPG containers shall not be located within dikes enclosing flammable liquid tanks.

Table B
Location of Containers.

Water capacity of each container gallons	Minimum Distances: Between containers†	Minimum Distances: From container to nearest important building or group of buildings, or a property line which may be built upon
2,001 to 30,000	5 ft	50 ft
30,001 to 70,000	¼ of sum of diameters of adjacent containers	75 ft
70,001 to 125,000	"	100 ft
125,001 to 200,000	"	200 ft

†The minimum distance requirement for spacing between containers when the water capacity of a container is 180,000 gal or more shall be at least 25 ft. The minimum distance requirement for spacing between groups of containers when a group of two or more containers has an aggregate water capacity of 180,000 gal or more shall be at least 25 ft.

251. Underground Containers.

(a) Underground containers shall include both buried and partially buried (or mounded) containers.

(b) Containers shall be located outside of any buildings. Buildings or roadways shall not be constructed over any underground containers. Sides of adjacent containers shall be separated by not less than 3 ft.

(c) When containers are installed parallel with ends in line, any number of containers may be in one group. When more than one row is installed, the adjacent ends of the tanks in each row shall be separated by not less than 10 ft.

(d) Containers and their loading stations shall be located not less than 50 ft from the nearest important building or group of buildings or line of adjacent property which may be built upon.

(e) The containers and their loading stations should be located not less than 50 ft from buildings occupied for generation, compression or purification of gas, or from outdoor installations essential to the maintenance of operation in such buildings. They should be located not less than 50 ft from aboveground storage of flammable liquids and from any buildings of such construction or occupancy which constitutes a severe exposure to any aboveground appurtenances of the underground installation in the event of fire or explosion in said buildings. If the underground installations by necessity are located closer than 50 ft to any such buildings or installations, then the latter shall be protected against the entry of escaping LPG, in such a manner as may be required and approved by the authority having jurisdiction.

252. Containers shall not be stacked one above the other.

253. The ground within 25 ft of any aboveground container shall be kept clear of readily ignitable material such as weeds and long dry grass.

254. In cases where containers are to be installed in heavily populated or congested areas, the authority having jurisdiction shall determine restrictions of individual tank capacity, total storage, distance to line of adjoining property which may be built on or other reasonable protective methods.

26. Installation of Storage Containers.

260. Aboveground Containers

(a) Every container shall be supported to prevent the concentration of excessive loads on the supporting portion of the shell or heads.

(b) Supports for containers shall be of solid masonry, concrete or steel. Structural metal supports may be employed when they are protected against fire in an approved manner. Steel supports shall be protected against fire with a material having a fire resistance rating of at least two hours. Steel skirts having only one opening shall be protected as above but fireproofing need only be applied to the outside of the skirt.

(c) Horizontal containers shall be mounted on saddles in such a manner as to permit expansion and contraction, not only of the container but also of the connected piping. Only two saddles shall be used.

(d) Suitable means to prevent corrosion shall be provided on that portion of the container in contact with the foundations or saddles.

(e) Containers should be kept properly painted or otherwise protected from the elements.

261. Underground Containers

(a) Buried containers shall be placed so that the top of the container is not less than 6-in. below the grade of the surrounding area. Partially buried (or mounded) containers shall have not less than 12-in. of cover, sufficient to provide surface drainage without erosion or other deterioration.

(b) The container manway shall not be covered with the backfill or mounding material. Under conditions where the container manway cover is below the ground level, a manway providing sufficient access shall be installed. No other part of the container shall be exposed.

(c) The containers shall be set on a firm foundation or firm undisturbed earth and surrounded with soft earth or sand well tamped into place. Provision shall be made to take care of settling and rotation.

(d) Containers shall be adequately protected against corrosion.

(e) Bottom connections to the container shall be prohibited. All connections shall be in the container manway or at openings along the top length of the container.

262. Field welding where necessary shall be made only on saddle plates or brackets which were applied by manufacturer of container, except as provided by the code under which the container was fabricated.

263. Secure anchorage or adequate pier height shall be provided to protect against container flotation wherever sufficiently high water might occur.

264. When flammable liquid storage tanks are in the same general area as LPG containers, the flammable liquid storage tanks shall be diked or diversion curbs or grading used to prevent accidentally escaping flammable liquids from flowing into LPG container areas.

265. The container storage area shall be fenced or otherwise protected where necessary and at least two points of access through the fencing shall be provided.

27. Re-Installation of Containers.

270. Containers once installed underground or aboveground which have been out of service for more than one year, shall not be re-installed aboveground or underground, unless they successfully withstand hydrostatic pressure retests at the pressure specified for the original hydrostatic tests as required by the code under which constructed, and show no evidence of serious corrosion. Re-installation of containers in all other respects shall be in accordance with all the provisions listed in this standard. (See Paragraph 265. See also Section 5 for relief valve requirements.)

28. Gaskets.

280. Gaskets for use on storage containers shall be fabricated with materials which have a melting point over 1000 F. Aluminum O-ring and spiral wound metal asbestos gaskets are recommended. Whenever a flange is opened the gasket should be replaced.

29. Filling Densities.

290. The "filling density" is defined as the percent ratio of the weight of the LPG in a container to the weight of water the container will hold at 60 F. The filling densities for storage containers shall not exceed the following:

MAXIMUM PERMITTED FILLING DENSITY

Specific Gravity at 60 F	Aboveground Containers	Underground Containers
.473—.480	41%	42%
.481—.488	42	43
.489—.495	43	44
.496—.503	44	45
.504—.510	45	46
.511—.519	46	47
.520—.527	47	48
.528—.536	48	49
.537—.544	49	50
.545—.552	50	51
.553—.560	51	52
.561—.568	52	53
.569—.576	53	54
.577—.584	54	55
.585—.592	55	56
.593—.600	56	57
.601—.608	57	58
.609—.617	58	59
.618—.626	59	60
.627—.634	60	61

291. The maximum liquid volume in percent of the total container capacity may be determined for LPG at any liquid temperature by using the formula shown in Appendix C.

Section 3: Piping, Valves, Gaging Devices

31. Piping Materials.

310. Seamless copper, brass, or steel pipe or tubing may be used for sizes ½-in. or under. All piping and pipe fittings over ½-in. size, connected to a storage container, shall be made of steel. All piping or tubing shall be designed and tested after installation at 1½ times the maximum working pressures to which it may be subjected.

311. Piping connections external to the container for sizes over 2-in. nominal pipe diameter shall be welded flanges or straight welded, with the possible exception of piping connections for excess flow valves and for relief valve risers.

312. The use of cast iron valves, pipe and fittings shall be prohibited in piping carrying LPG in the liquid phase.

313. Valve seat material, packing, gaskets, etc., shall be resistant to the action of LPG in the liquid phase.

314. All piping, tubing, fittings and the valves shall be tested after assembly and proved free from leaks at not less than normal operating pressures. Test shall not be made with a flame.

315. Provision shall be made for expansion, contraction, jarring and vibration, and for settling.

316. Piping outside buildings may be buried, aboveground, or both, but shall be well supported and protected against physical damage and corrosion.

32. Container Valves and Accessories.

320. All shut-off valves and accessory equipment (liquid or gas) shall be suitable for use with LPG, and designed for not less than the maximum pressure to which they may be subjected. Valves which may be subjected to container pressure shall have a rated working pressure of at least 250 psig. Cast iron valves, piping and fittings shall be prohibited on LPG containers and their connections.

321. All connections to containers, except safety relief connections and gaging devices shall have shut-off valves located as close to the container as practicable.

322. Excess flow valves where required by this standard shall close automatically at those rated flows of vapor or liquid as specified by the manufacturer. The connections or line including valves, fittings, etc., downstream of an excess flow valve shall have a greater capacity than the rated flow of the excess flow valve.

323. Except as provided in Paragraphs 324 and 342 all liquid and vapor connections on containers except safety relief connections shall be equipped with approved automatic excess flow valves or with back pressure check valves.

324. Openings from a container or through fittings attached directly on the container to which pressure gage connection is made need not be equipped with an excess flow valve if such openings are not larger than No. 54 drill size.

325. Excess flow and back pressure check valves where required by this standard shall be located inside of the container or at a point outside where the line enters the container; in the latter case, installation shall be made in such a manner that any undue stress beyond the excess flow or back pressure check valve will not cause breakage between the container and such valve.

326. Excess flow valves shall be designed with a by-pass, not to exceed a No. 60 drill size opening to allow equalization of pressures.

327. All inlet and outlet connections except safety valves, liquid level gaging devices and pressure gages on any container shall be labeled or color coded to designate whether they are connected to vapor or liquid space. Labels may be on valves.

328. Each storage container shall be provided with a suitable pressure gage.

33. Filler and Discharge Pipes, Manifolds.

330. Piping connections between container and manifold should be designed to provide adequate allowances for contraction, expansion, vibration, and settlement. Compression type couplings shall not be considered suitable for this purpose.

331. It is desirable that liquid manifold connections be located at non-adjacent ends of parallel rows of containers.

332. The use of non-metallic hose is prohibited for interconnecting stationary containers.

333. A good test for determination of piping stresses consists of unbolting piping at a flange and noting whether the flange remains in proper alignment.

334. The filling pipe inlet terminal shall not be located inside a building. Such terminals shall be located not less than 10 ft from any building, and preferably not less than 5 ft from any driveway, and shall be properly supported and protected from physical damage.

335. A shut-off valve shall be provided in liquid piping for each section of pipe containing 500-gal capacity when the pipe is within 300 ft of storage containers or other important aboveground structures.

336. When the liquid line manifold connecting containers in a group has a volumetric capacity of more than 100-gal, such container manifolds shall be located not less than 100 ft from the nearest adjacent property owned by others which may be built upon. The manifold piping terminates at the first line valve which may be used to isolate the manifolded containers from any other part of the liquid line system.

337. If more than three storage containers discharge liquid into a manifold whose nominal diameter is greater than 2 in., and if the flow capacity of such manifold is less than the total

discharge capacity of the discharge lines from the containers, one of the following for each container shall be provided:

(a) A remotely controlled external shut-off valve in combination with an excess flow valve.

(b) A remotely controlled quick-closing valve which shall remain closed except during operating periods. The mechanism for such valves may be provided with a secondary control equipped with a fusible release (not over 220 F melting point) which will cause the quick-closing valve to close automatically in case of fire.

34. Liquid Level Gaging Device.

340. Each container shall be equipped with a liquid level gaging device of approved design, for example, a rotary gage, slip tube, an automatic outage tank, magnetic or fixed tube device. If the liquid level gaging device is a float type or a pressure differential type, the container shall also be provided with a fixed dip tube, slip tube, rotary gage or similar device.

341. All gaging devices shall be arranged so that the maximum liquid level for butane, for a 50-50 mixture of butane and propane, and for propane, to which the container may be filled is readily determinable.

342. Gaging devices that require bleeding of the product to the atmosphere, such as the rotary tube, fixed tube and slip tube, shall be so designed that the bleed valve maximum opening is not larger than a No. 54 drill size, unless provided with an excess flow valve.

343. Gaging devices shall have a design working pressure of at least 250 psig.

344. Length of a fixed tube device shall be designed to indicate the maximum level to which the container may be filled for the product contained. This level shall be based on the volume of the product at 40 F at its maximum permitted filling density for aboveground containers and at 50 F for buried containers. (Refer to Appendix D in NFPA-59 for calculating filling point for which tube shall be designed.)

345. Gage glasses of the columnar type shall not be permitted.

35. Hose Specifications.

350. Hose shall be fabricated of materials that are resistant to the action of LPG.

351. Hose subject to container pressure shall be designed for a bursting pressure of not less than five times the pressure for which the container was designed. Hose connections when made shall be capable of withstanding a test pressure of twice the pressure for which the container is designed.

352. Hose and hose connections located on the low-pressure side of regulators or reducing valves shall be designed for a bursting pressure of not less than 125 psi but not less than five times the pressure setting of the safety relief devices protecting that portion of the system. There shall be no leakage from assembled hose connections.

36. Drips, Pits and Drains.

360. Where vaporized gas may condense, suitable means shall be provided for re-vaporization or disposal of the condensate.

361. Every effort should be made to avoid the use of pits. If pits are used they shall be fitted with continuous automatic flammable vapor detecting devices equipped with an alarm. No drains or blow-off lines shall be directed into or in proximity to sewer systems used for other purposes.

37. Pumps and Compressors.

370. Each pump and compressor shall be suitable for the LPG service intended. Each pump and compressor shall be marked with its maximum working pressure.

38. Protection of Container Accessories, Grounding.

380. Valves, regulating, gaging, and other container accessory equipment shall be protected against tampering and physical damage.

NOTE: The use of locks is not usually desirable because it prevents access in case of emergency.

381. All connections on underground containers shall be located within a substantial dome, housing, or manhole and protected by a substantial round cover. (See Paragraph 541.)

382. Aboveground containers shall be electrically grounded in an effective manner. (See Report of NFPA Committee on Static Electricity, No. 77.)

Section 4: Vaporizers

41. General.

410. LPG storage containers shall not be directly heated with open flames.

411. Heating or cooling coils shall not be installed inside of a storage container.

412. Vaporizers shall not be equipped with fusible plugs for pressure relief.

413. Vaporizer houses shall not have drains to sewers or sump pits.

42. Vaporizers Not Directly Heated With Open Flames.

420. Vaporizers constructed in accordance with the requirements of the ASME Unfired Pressure Vessel Code shall be permanently marked as follows:

(a) With the code marking signifying the specifications to which vaporizer is constructed.

(b) With the allowable working pressure and temperature for which the vaporizer is designed.

(c) With the sum of the outside surface area and the inside heat exchange surface area expressed in square feet.

(d) With the name or symbol of the manufacturer, date of manufacture, and serial number.

421. Vaporizers having an inside diameter of 6 in. or less exempted by paragraph U-1(a) of the ASME Unfired Pressure Vessel Code shall have a design working pressure not less than 250 psig and need not be permanently marked.

422. Vaporizers shall not be installed in the same room with units furnishing air other than for a LPG mixing device. Vaporizers may be installed in buildings, rooms, sheds, or lean-tos, other than those in which open flames or fires may exist. Such structures shall be of light fire resistive construction or equivalent, well ventilated near the floor line and at the highest point in the roof.

423. A shut-off valve shall be installed on the liquid line to the LPG vaporizer unit at least 50 ft from the vaporizer building.

424. The heating medium lines into and leaving the vaporizer shall be provided with suitable means for preventing the flow of gas into the heat systems in the event of tube rupture in the vaporizer. Vaporizers shall be provided with suitable means to prevent liquid passing from the vaporizers to the gas discharge piping.

425. The device that supplies the necessary heat for producing steam, hot water, or other heating medium shall be separated from all compartments or rooms containing LPG vaporizers, pumps, and central gas mixing devices by a wall of substantially fire resistive material and vaportight construction.

43. Direct Fired Vaporizers.

430. Each vaporizer shall be marked to show the name of the manufacturer; rated British Thermal Unit input to burners; the area of the heat exchange surface in square feet; and the maximum vaporizing capacity in gallons per hour, and date and serial number.

431. No direct fired vaporizers shall be located closer than 50 ft to line of adjoining property upon which structures may be built. They shall also be located a minimum distance of 50 ft away from any LPG storage container.

432. No direct fired vaporizer shall be connected to a container that has a storage capacity in gallons, less than 10 times the hourly capacity of the vaporizer in gallons. Vaporizers may be connected to the liquid section or the gas section of the storage container, or both; but in any case there shall be at the container a manually operated valve in each connection to permit complete shutting off, when desired, all flow of gas or liquid from container to vaporizer.

433. Vaporizers may be installed in buildings, rooms, housings, sheds, or lean-tos used exclusively for vaporizing or mixing of LPG. All vaporizer housing structures shall be of light fire resistive construction, well ventilated near the floor line and the highest point of the roof.

434. When vaporizers and mixing equipment are installed in structures that house other facilities, the vaporizers and mixing equipment room shall be separated from the other parts of the building with fire resistive, vaportight walls.

435. Vaporizers shall be provided with suitable automatic means to prevent liquid passing from the vaporizer to the gas discharge piping of the vaporizer.

436. Vaporizers shall be provided with a means for turning off the gas to the main burner and pilot from a remote location.

437. Vaporizers shall be equipped with automatic safety devices to shut off the flow of fuel to main burners and pilot, if the ignition device should fail.

438. Pressure control equipment which is a pertinent part of the vaporizer, if located within 10 ft of the vaporizer, shall be separated from the open flame by a substantial vaportight, fire resistive partition or partitions.

439. No direct fired vaporizer shall raise the product pressure over the designed working pressure of the vaporizer equipment.

Section 5: Relief Devices

51. General.

All relief device installations shall comply with the following:

510. Relief devices on containers shall be so arranged that the possibility of tampering will be minimized; if the pressure setting or adjustment is external, the relief devices shall be provided with an approved means for sealing the adjustment.

511. Each container relief device shall be plainly and permanently marked with the "Container Type," of the pressure vessel on which the device is designed to be installed, with the pressure in psig at which the device is set to start to discharge, with the actual rate of discharge of the device at its full open position in cubic feet per minute of air at 60 F and atmospheric pressure, and with the manufacturer's name and catalogue number; for

example, T-200 — 250—15,000 AIR — indicating that the device is suitable for use on a Type 200 container, that it is set to start to discharge at 250 psig, and that its rate of discharge at full open position (See 532 and 533) is 15,000 cu ft per min of air.

512. The capacity of container relief valve discharge flow-rate shall be determined by use of Appendix A.

513. Connections to which relief devices are attached, such as couplings, flanges, nozzles, and discharge lines for venting, shall have internal dimensions that will not restrict the net relief area.

514. The size of the relief device outlet connection shall not be smaller in diameter than the nominal size of the relief outlet connection and shall not appreciably restrict flow through the relief.

515. All container relief devices shall be located on the containers and shall be connected with the vapor space of the container.

516. No shut-off valve shall be installed between the relief device and the container, equipment, or piping to which the relief device is connected except that a shut-off valve may be used where the arrangement of this valve is such that full required capacity flow through the relief device is always afforded.

NOTE: The above exception is made to cover such cases as a three-way valve installed under two relief devices, each of which has the required rate of discharge. The installation will allow either of the reliefs to be closed but does not allow both reliefs to be closed at the same time. Another exception to this may be where two separate reliefs are installed with individual shut-off valves. In this case the two shut-off valve stems shall be mechanically inter-connected in a manner which will allow full required flow of one relief at all times.

517. Relief device discharge vents shall be installed in a manner which will provide protection against physical damage and such discharge pipes shall be fitted with loose raincaps. Return bends and restrictive pipe fittings shall not be permitted.

518. If desired, discharge lines from two or more relief devices located on the same unit, or similar lines from two or more different units, except those located on storage containers, may be run into a common discharge header, provided that the cross sectional area of such header be at least equal to the sum of the cross sectional area of the individual discharge lines, and that the setting of relief devices is the same.

519. Discharge from a relief device shall not terminate in any building, beneath any building, or in any other kind of confined area. The discharge from all relief devices, except those installed between shut-off valves, shall be piped to a point not less than 3 ft above the highest point of any building within 50 ft.

52. Testing Relief Devices.

520. Frequent testing of relief devices, as would be required where there is a probable increase or decrease in the releasing pressure of the device due to clogging, sticking, corrosion or exposure to elevated temperatures, is not necessary for such devices on LPG containers for the following reasons:

(a) The gases are so-called "sweet gases," *i.e.*, they have no corrosive effect on metals; the devices are constructed of materials not readily subject to corrosion and are protected against the weather when installed in pressure vessels. Further, the temperature variations are not sufficient to bring about any permanent set of spring mechanisms.

(b) Therefore the testing and inspecting of relief devices to check relief pressure settings is required only at about five-year intervals.

53. On Aboveground Containers.

530. Every container shall be provided with spring loaded relief valves or their equivalent.

531. The discharge from the relief devices shall be vented away from the container, and unobstructed to the open air in a manner to prevent any impingement of escaping gas upon the container, adjacent containers, piping and other equipment. The vents shall be fitted with loose fitting raincaps. Suitable provision shall be made to prevent any liquid or condensate that may accumulate inside the relief device or its vent from rendering the relief device inoperative. If a bottom drain is used, a means shall be provided to protect the container, adjacent containers, piping of equipment against impingement of flame resulting from ignition of product escaping from the drain. The vent piping shall extend upward at least 7 ft above the top of the container.

532. Container relief device shall be set to start to discharge as follows, with relation to the design working pressure of the container:

Containers	*Minimum*	*Maximum**
1949 and earlier Edition of ASME Code: Par. U-68, U-69	110%	125%
1949 edition of ASME Code: Par. U-200, U-201; 1950 & 1952 Editions of ASME Code	88	100
All Editions of API-ASME Code	88	100

*Note: A plus tolerance of 10% is permitted.

533. Relief devices on containers shall be constructed to discharge at not less than the rates shown in Appendix A, before the pressure is in excess of 120 percent of the maximum permitted start to discharge pressure setting of the devices.

534. In certain locations sufficiently sustained sun temperatures prevail which will require the use of a lower vapor pressure product to be stored or the use of a higher designed pressure vessel in order to prevent the container relief device from opening as a result of these temperatures. As an alternative the containers may be protected by cooling devices such as water sprays, by shading, or other effective means.

54. On Underground Containers.

540. Relief devices shall meet all conditions outlined for Aboveground Containers but the discharge in this case shall be piped vertically and directly upward to a point at least 7 ft above the ground.

541. When there is a probability of the manhole or housing becoming flooded, the discharge from regulator vent lines should be above such water level. All manholes or housings shall be provided with ventilated louvers or their equivalent.

55. On Vaporizers.

550. Each vaporizer shall be provided with a relief device providing an effective rate of discharge in accordance with Appendix B.

551. Relief valves on direct fired vaporizers shall be located so that they shall not be subjected to temperatures in excess of 140 F. (See Paragraph 51 for other requirements on relief devices.)

56. Between Shut-Off Valves.

560. A relief device shall be installed between each pair of shut-off valves on LPG liquid piping so as to relieve into a safe atmosphere. It is recommended that the start to discharge pressure of such relief devices be not in excess of 500 psig.

57. At Discharge of Final Stage Regulators.

570. When the discharge pressure from the final stage regulator is not more than 5 lb, the low-pressure side shall be equipped with a relief device, set to relieve at not less than 2 times, and not more than 3 times the discharge pressure but not more than 5 lb in excess of the discharge pressure. When the discharge pressure is more than 5 lb, the relief shall be set to not less than 1¼ times and not more than 2 times the discharging pressure. Regulator breather vents shall be piped outside the building and equipped with insect-proof terminal screens.

Section 6: Handling

61. Transfer of Liquids Within a Utility Plant.

610. LPG in liquid form may be transferred from tank cars, or tank trucks, or storage within a utility plant either by liquid pump or by pressure differential.

(a) Pumps and compressors used for transferring LPG shall be designed for the product handled.

(b) Pressure differential for transferring liquid should be developed by a vapor compressor which takes suction from the vapor space of the LPG container being filled and discharges into the vapor space of the container being emptied.

611. Under certain conditions, it may be necessary to create a pressure differential by using fuel gas, air, or inert gas, which is at a pressure higher than the pressure of the LPG in the container being filled. This may be done under the following conditions:

(a) Adequate precautions must be taken to prevent LPG from flowing back into the fuel gas, air, or inert gas line or system by installing two back flow check valves in series in these lines at the point where they connect into the LPG system. In addition, a manually operated positive shut-off valve shall be installed at this point.

(b) Any fuel gas, air, or inert gas used to obtain a pressure differential to move liquid LPG shall be noncorrosive and dried to avoid stoppage by freezing.

(c) If a fuel gas, air, or inert gas is used to obtain a pressure differential to move liquid LPG, consideration should be given, after the operation is discontinued, to removing the fuel gas, air, or inert gas from the container into which it was placed, such as by venting. This should be done only if the vented gas can be conducted to a proper vent, preferably a distance from the plant and then properly disposed of.

(d) Before any fuel gas, air, or inert gas is placed in a tank car for unloading LPG by pressure differential, permission should be obtained from the vendor of the LPG to introduce such vapors into the tank car or a tank truck.

612. At least one attendant shall remain close to the transfer connection from the time the connections are first made until they are finally disconnected, during the transfer of product.

613. The maximum vapor pressure of the product at 100 F which may be transferred into a container shall be in accordance with Paragraph 230.

614. Where needed unloading piping or hoses shall be provided with suitable bleeder valves for relieving pressure before disconnection.

615. Precaution shall be exercised to assure that only those gases for which the system is designed, examined, and listed are employed in its operation, particularly with regard to pressures.

62. Tank Car Loading and Unloading Point.

620. The track of tank car siding shall be relatively level.

621. A TANK CAR CONNECTED sign, as covered by ICC (Interstate Commerce Commission) rules, shall be installed at the active end or ends of the siding while the tank car is connected for unloading.

622. While cars are on side-track for unloading, the wheels at both ends shall be blocked on the rail.

623. A man shall be in attendance at all times while the tank car or cars are being unloaded.

624. The pipeline to which the tank car unloading hoses are connected shall be equipped with a back flow check valve to prevent discharge of the LPG from the receiving container and line in case of rupture of line hose or fittings.

625. The tank car unloading point should be located with due safety consideration to the following:

(a) Proximity to railroad and highway traffic.
(b) The distance of such unloading point from adjacent property.
(c) With respect to buildings on installer's property.
(d) Nature of occupancy.
(e) Topography.
(f) Type of construction of buildings.
(g) Number of tank cars that may be safely unloaded at one time.
(h) Frequency of unloading.

626. Where practical, the distance of the tank car unloading point should conform to the distance in Paragraph 250 except that lesser distances may be used, keeping in mind the above items and upon approval of the authority having jurisdiction.

Section 7: Fire Protection

71. Fire Protection.

710. The wide range in the size, design, and location of utility plant LPG installations makes the recommendations of any specific kind or method of fire protection impractical. The planning of effective fire protection should initially be coordinated with the protection practices followed in other sections of the particular utility company and should give due consideration to the requirements of the authority having jurisdiction.

711. Gas fires should not be extinguished until the source of the burning gas can be shut off. Remotely operated or remotely located pipeline valves may be advantageously used for fire control under many circumstances (see Paragraphs 335, 337 and 423).

712. Hand or wheeled fire extinguishers designed for gas fires, preferably of the dry chemical type, should be available at each strategic location within an LPG plant.

713. Supplies of water may be utilized through hose lines preferably equipped with combination (spray and straight stream) nozzles to permit widest adaptability in fire control. If sufficient quantities of water can be made available, complete water spray protection can be given consideration. The water is used for the sole purpose of cooling equipment, foundations, and piping. It shall not be relied upon for extinguishing gas fires.

714. Fire-resistive insulation may be utilized for protecting metal against heat. Care in selecting and applying such insulation is necessary since effectiveness is dependent on its ability to stay in place on a container during a fire.

715. Where standard watchman service is provided it shall be extended to the LPG installation; such personnel shall be properly trained.

716. Suitable roadways or means of access shall be provided for extinguishing equipment such as wheeled extinguishers or other fire department apparatus.

717. Routine fire drills and inspections should be scheduled and operating personnel thoroughly trained in the use of available fire-fighting equipment and the location and use of all gas and liquid piping and valves.

Appendix A.

Minimum Required Rate of Discharge in cubic feet per minute of air at 120% of the maximum permitted start to discharge pressure for safety relief devices to be used on containers other than those constructed in accordance with Interstate Commerce Commission specifications.

Surface Area Sq Ft	Flow Rate CFM Air	Surface Area Sq Ft	Flow Rate CFM Air	Surface Area Sq Ft	Flow Rate CFM Air
20 or less	626	170	3620	600	10170
25	751	175	3700	650	10860
30	872	180	3790	700	11550
35	990	185	3880	750	12220
40	1100	190	3960	800	12880
45	1220	195	4050	850	13540
50	1330	200	4130	900	14190
55	1430	210	4300	950	14830
60	1540	220	4470	1000	15470
65	1640	230	4630	1050	16100
70	1750	240	4800	1100	16720
75	1850	250	4960	1150	17350
80	1950	260	5130	1200	17960
85	2050	270	5290	1250	18570
90	2150	280	5450	1300	19180
95	2240	290	5610	1350	19780
100	2340	300	5760	1400	20380
105	2440	310	5920	1450	20980
110	2530	320	6080	1500	21570
115	2630	330	6230	1550	22160
120	2720	340	6390	1600	22740
125	2810	350	6540	1650	22320
130	2900	360	6690	1700	23900
135	2990	370	6840	1750	24470
140	3080	380	7000	1800	25050
145	3170	390	7150	1850	25620
150	3260	400	7300	1900	26180
155	3350	450	8040	1950	26750
160	3440	500	8760	2000	27310
165	3530	550	9470		

Surface Area = Total outside surface area of container in square feet.

When the surface area is not stamped on the name plate or when the marking is not legible, the area can be calculated by using one of the following formulas:

(1) Cylindrical container with hemispherical heads
Area = Overall length × outside diameter × 3.1416
(2) Cylindrical container with semi-ellipsoidal heads
Area = (Overall length + .3 outside diameter) × outside diameter × 3.1416.
(3) Spherical container
Area = Outside diameter squared × 3.1416

Flow Rate-CFM Air = Required flow capacity in cubic feet per minute of air at standard conditions, 60F and atmospheric pressure (14.7 psia).

The rate of discharge may be interpolated for intermediate values of surface area. For containers with total outside surface area greater than 200 sq ft. the required flow rate can be calculated using the formula, Flow Rate-CFM Air = $53.632\ A^{0.82}$.

Where

A = total outside surface area of the container in square feet.

Values not marked "Air" have flow rate markings in cu ft per min of LPG that were calculated by using the factors listed below. These same factors may be used to reconvert to cu ft per min of air for use in present Appendix A.

Air Conversion Factors

Container Type				
100	125	150	175	200
.162	1.142	1.113	1.078	1.010

Appendix B.

Minimum Required Rate of Discharge for Safety Relief Valves for Liquefied Petroleum Gas Vaporizers (Steam Heated, Water Heated, and Direct Fired.)

The minimum required rate of discharge for relief valves shall be determined as follows:

1. Obtain the total surface area by adding the surface area of vaporizer shell in square feet directly in contact with LPG and the heat exchange surface area in square feet directly in contact with LPG.
2. Obtain the minimum required rate of discharge in cubic feet of air per minute, at 60 F and 14.7 psia from Appendix A for this total surface area.

Appendix C.

Method of Calculating Maximum Liquid Volume Which Can Be Placed in a Container at Any Liquid Temperature.

The quantity of LPG which may be placed in a container is dependent upon the temperature of the liquid and the maximum permitted filling density in addition to the size of the container.

The filling density depends on: The size of tank, whether it is installed aboveground or underground, and the specific gravity of the liquid LPG at 60 F placed in the container. Filling density values are given in Paragraph 290. The liquid temperature should be obtained by measuring the temperature of the liquid LPG in the container with a thermometer placed in a thermometer well installed in the tank.

Knowing the liquid temperature and the filling density, the maximum volume of liquid LPG which may be placed in a container can be determined as follows:

$$V = \frac{D}{G \times F}$$

Where

V = maximum liquid volume (in percent of total container capacity) which shall be placed in a container when the liquid temperature is T.
D = filling density from Paragraph 290 in percent.
G = specific gravity of LPG at 60 F placed in container.
F = correction factor from following table for correcting liquid volume from 60 F to volume at temperature T. The correction factor is obtained by finding the specific gravity at 60 F (G) in the column at the top of the table and coming down this column till the actual liquid temperature T is found. The correction factor corresponding to this specific gravity and temperature is then read. Interpolation is permitted. (Table on following page.)
T = temperature of liquid LPG in container in degrees Fahrenheit.

After obtaining V from the above formula the actual maximum gallons of LPG which may be placed in a container is obtained by multiplying the water capacity of the container by $\frac{V}{100}$

Example:

Assume an aboveground container with 10,000 gal water capacity
Propane with a specific gravity of 0.508 at 60 F to be placed in container
Filling density from Paragraph 290 for abovegroud container in which a product having a specific gravity at 60 F of 0.508 is to be placed is 45 percent
To determine maximum quantity that may be placed in container when the liquid temperature is 60 F

$$V = \frac{45 \times 10{,}000}{0.508 \times 100} = 8850 \text{ gal}$$

When liquid temperature is 82 F use correction factor in the table (Appendix D, NFPA Standard 59) for specific gravity at 60 F of 0.508 and a liquid temperature of 82 F (which is 0.963)

$$V = \frac{45 \times 10{,}000}{0.508 \times 0.963 \times 100} = 9200 \text{ gal}$$

VOLUME CORRECTION FACTORS

SPECIFIC GRAVITIES AT 60° F./60° F.

Observed Temperature Degrees Fahrenheit	0.500	Propane 0.5079	0.510	0.520	0.530	0.540	0.550	0.560	iso-Butane 0.5631	0.570	0.580	n-Butane 0.5844	0.590	0.600	0.610	0.620	iso-Pentane 0.6246	0.630	n-Pentane 0.6310	0.640	0.650	0.660	0.670	0.680	0.690	0.700
	VOLUME CORRECTION FACTORS																									
−50	1.160	1.155	1.153	1.146	1.140	1.133	1.127	1.122	1.120	1.116	1.111	1.108	1.106	1.102												
−45	1.153	1.148	1.146	1.140	1.134	1.128	1.122	1.117	1.115	1.111	1.106	1.103	1.101	1.097												
−40	1.147	1.142	1.140	1.134	1.128	1.122	1.117	1.111	1.110	1.106	1.101	1.099	1.097	1.093												
−35	1.140	1.135	1.134	1.128	1.122	1.116	1.112	1.106	1.105	1.101	1.096	1.094	1.092	1.088												
−30	1.134	1.129	1.128	1.122	1.116	1.111	1.106	1.101	1.100	1.096	1.092	1.090	1.088	1.084												
−25	1.127	1.122	1.121	1.115	1.110	1.105	1.100	1.095	1.094	1.091	1.087	1.085	1.083	1.080												
−20	1.120	1.115	1.114	1.108	1.104	1.099	1.095	1.090	1.089	1.086	1.082	1.080	1.079	1.076												
−15	1.112	1.109	1.107	1.102	1.097	1.093	1.089	1.084	1.083	1.080	1.077	1.075	1.074	1.071												
−10	1.105	1.102	1.100	1.095	1.091	1.087	1.083	1.079	1.078	1.075	1.072	1.071	1.069	1.066												
−5	1.098	1.094	1.094	1.089	1.085	1.081	1.077	1.074	1.073	1.070	1.067	1.066	1.065	1.062												
0	1.092	1.088	1.088	1.084	1.080	1.076	1.073	1.069	1.068	1.066	1.063	1.062	1.061	1.058	1.055	1.053	1.052	1.051	1.051	1.050	1.048	1.046	1.045	1.044	1.043	1.042
2	1.089	1.086	1.085	1.081	1.077	1.074	1.070	1.067	1.066	1.064	1.061	1.060	1.059	1.056	1.053	1.051	1.050	1.049	1.049	1.048	1.046	1.045	1.044	1.043	1.042	1.041
4	1.086	1.083	1.082	1.079	1.075	1.071	1.068	1.065	1.064	1.062	1.059	1.058	1.057	1.054	1.051	1.049	1.049	1.048	1.048	1.047	1.045	1.043	1.042	1.041	1.041	1.039
6	1.084	1.080	1.080	1.076	1.072	1.069	1.065	1.062	1.061	1.059	1.057	1.055	1.054	1.052	1.050	1.048	1.047	1.046	1.046	1.045	1.043	1.042	1.041	1.040	1.039	1.038
8	1.081	1.078	1.077	1.074	1.070	1.066	1.063	1.060	1.059	1.057	1.055	1.053	1.052	1.050	1.048	1.046	1.045	1.045	1.045	1.044	1.042	1.040	1.039	1.038	1.037	1.036
10	1.078	1.075	1.074	1.071	1.067	1.064	1.061	1.058	1.057	1.055	1.053	1.051	1.050	1.048	1.046	1.044	1.044	1.043	1.043	1.042	1.040	1.039	1.038	1.037	1.036	1.035
12	1.075	1.072	1.071	1.068	1.064	1.061	1.059	1.056	1.055	1.053	1.051	1.049	1.048	1.046	1.044	1.042	1.042	1.041	1.041	1.040	1.038	1.037	1.036	1.035	1.035	1.034
14	1.072	1.070	1.069	1.066	1.062	1.059	1.056	1.053	1.053	1.051	1.049	1.047	1.046	1.044	1.042	1.041	1.040	1.039	1.039	1.038	1.037	1.036	1.035	1.034	1.033	1.032
16	1.070	1.067	1.066	1.063	1.060	1.056	1.054	1.051	1.050	1.048	1.046	1.045	1.044	1.043	1.041	1.039	1.039	1.038	1.038	1.036	1.036	1.034	1.033	1.032	1.032	1.031
18	1.067	1.065	1.064	1.061	1.057	1.054	1.051	1.049	1.048	1.046	1.044	1.043	1.042	1.041	1.039	1.038	1.037	1.036	1.036	1.035	1.034	1.033	1.032	1.031	1.030	1.029
20	1.064	1.062	1.061	1.058	1.054	1.051	1.049	1.046	1.046	1.044	1.042	1.041	1.040	1.039	1.037	1.036	1.035	1.034	1.034	1.033	1.032	1.031	1.030	1.029	1.029	1.028
22	1.061	1.059	1.058	1.055	1.052	1.049	1.046	1.044	1.044	1.042	1.040	1.039	1.038	1.036	1.035	1.034	1.033	1.032	1.032	1.031	1.030	1.030	1.029	1.028	1.028	1.027
24	1.058	1.056	1.055	1.052	1.049	1.046	1.044	1.042	1.042	1.040	1.038	1.037	1.036	1.034	1.033	1.032	1.032	1.031	1.031	1.030	1.029	1.028	1.027	1.026	1.026	1.025
26	1.055	1.053	1.052	1.049	1.047	1.044	1.042	1.039	1.039	1.037	1.036	1.036	1.034	1.033	1.032	1.031	1.030	1.029	1.029	1.028	1.027	1.027	1.026	1.025	1.024	1.024
28	1.052	1.050	1.049	1.047	1.044	1.041	1.039	1.037	1.037	1.035	1.034	1.034	1.032	1.031	1.030	1.029	1.028	1.028	1.028	1.027	1.026	1.025	1.024	1.023	1.023	1.022
30	1.049	1.047	1.046	1.044	1.041	1.039	1.037	1.035	1.035	1.033	1.032	1.032	1.030	1.029	1.028	1.027	1.027	1.026	1.026	1.025	1.024	1.024	1.023	1.022	1.022	1.021
32	1.046	1.044	1.043	1.041	1.038	1.036	1.035	1.033	1.033	1.031	1.030	1.030	1.028	1.027	1.026	1.025	1.025	1.024	1.024	1.023	1.022	1.022	1.021	1.021	1.020	1.020
34	1.043	1.041	1.040	1.038	1.036	1.034	1.032	1.031	1.030	1.029	1.028	1.028	1.026	1.025	1.024	1.023	1.023	1.022	1.022	1.022	1.021	1.021	1.020	1.019	1.019	1.018
36	1.039	1.038	1.037	1.035	1.033	1.031	1.030	1.028	1.028	1.027	1.025	1.025	1.024	1.023	1.023	1.022	1.021	1.021	1.021	1.020	1.019	1.019	1.018	1.018	1.017	1.017
38	1.036	1.035	1.034	1.032	1.031	1.029	1.027	1.026	1.025	1.025	1.023	1.023	1.022	1.021	1.021	1.020	1.020	1.019	1.019	1.019	1.018	1.018	1.017	1.016	1.016	1.015
40	1.033	1.032	1.031	1.029	1.028	1.026	1.025	1.024	1.023	1.023	1.021	1.021	1.020	1.019	1.019	1.018	1.018	1.017	1.017	1.017	1.016	1.016	1.015	1.015	1.014	1.014
42	1.030	1.029	1.028	1.027	1.025	1.024	1.023	1.022	1.021	1.021	1.019	1.019	1.018	1.018	1.017	1.016	1.016	1.015	1.015	1.015	1.014	1.014	1.013	1.013	1.013	1.013
44	1.027	1.026	1.025	1.023	1.022	1.021	1.020	1.019	1.019	1.018	1.017	1.017	1.016	1.016	1.015	1.014	1.014	1.014	1.014	1.013	1.013	1.013	1.012	1.012	1.011	1.011
46	1.023	1.022	1.022	1.021	1.020	1.018	1.018	1.017	1.016	1.016	1.015	1.015	1.014	1.014	1.013	1.013	1.013	1.012	1.012	1.012	1.011	1.011	1.010	1.010	1.010	1.010
48	1.020	1.019	1.019	1.018	1.017	1.016	1.015	1.014	1.014	1.013	1.013	1.013	1.012	1.012	1.011	1.011	1.011	1.011	1.011	1.010	1.010	1.010	1.009	1.009	1.008	1.008
50	1.017	1.016	1.016	1.015	1.014	1.013	1.013	1.012	1.012	1.011	1.011	1.011	1.010	1.010	1.009	1.009	1.009	1.009	1.009	1.008	1.008	1.008	1.007	1.007	1.007	1.007
52	1.014	1.013	1.012	1.012	1.011	1.010	1.010	1.009	1.009	1.009	1.009	1.009	1.008	1.008	1.007	1.007	1.007	1.007	1.007	1.007	1.006	1.006	1.006	1.006	1.006	1.005
54	1.010	1.010	1.009	1.009	1.008	1.008	1.007	1.007	1.007	1.007	1.006	1.006	1.006	1.006	1.006	1.005	1.005	1.005	1.005	1.005	1.005	1.005	1.004	1.004	1.004	1.004
56	1.007	1.007	1.006	1.006	1.005	1.005	1.005	1.005	1.005	1.005	1.004	1.004	1.004	1.004	1.004	1.004	1.004	1.003	1.003	1.003	1.003	1.003	1.003	1.003	1.003	1.003
58	1.003	1.003	1.003	1.003	1.003	1.003	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.001	1.001	1.001	1.001
60	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
62	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.999	0.999	0.999
64	0.993	0.993	0.994	0.994	0.994	0.994	0.995	0.995	0.995	0.995	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.997	0.997	0.997	0.997	0.997	0.997	0.997
66	0.990	0.990	0.990	0.990	0.991	0.992	0.992	0.993	0.993	0.993	0.993	0.993	0.993	0.994	0.994	0.994	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.996	0.996	0.996
68	0.986	0.986	0.987	0.987	0.988	0.989	0.990	0.990	0.990	0.990	0.991	0.991	0.991	0.992	0.992	0.993	0.993	0.993	0.993	0.994	0.994	0.994	0.994	0.994	0.994	0.994
70	0.983	0.983	0.984	0.984	0.985	0.986	0.987	0.988	0.988	0.988	0.989	0.989	0.989	0.990	0.990	0.991	0.991	0.991	0.991	0.992	0.992	0.992	0.992	0.993	0.993	0.993
72	0.979	0.980	0.981	0.981	0.982	0.983	0.984	0.985	0.986	0.986	0.987	0.987	0.987	0.988	0.988	0.989	0.989	0.989	0.989	0.990	0.990	0.990	0.991	0.991	0.992	0.992
74	0.976	0.976	0.977	0.978	0.980	0.980	0.982	0.983	0.983	0.984	0.985	0.985	0.985	0.986	0.986	0.987	0.987	0.987	0.987	0.988	0.988	0.989	0.989	0.990	0.990	0.990
76	0.972	0.973	0.974	0.975	0.977	0.978	0.979	0.980	0.981	0.981	0.982	0.982	0.983	0.984	0.985	0.986	0.986	0.986	0.986	0.987	0.987	0.987	0.988	0.988	0.989	0.989
78	0.969	0.970	0.970	0.972	0.974	0.975	0.977	0.978	0.978	0.979	0.980	0.980	0.981	0.982	0.983	0.984	0.984	0.984	0.984	0.985	0.986	0.986	0.986	0.987	0.987	0.987
80	0.965	0.967	0.967	0.969	0.971	0.972	0.974	0.975	0.976	0.977	0.978	0.978	0.979	0.980	0.981	0.982	0.982	0.982	0.982	0.983	0.984	0.984	0.985	0.985	0.986	0.986
82	0.961	0.963	0.963	0.966	0.968	0.969	0.971	0.972	0.973	0.974	0.976	0.976	0.977	0.978	0.979	0.980	0.980	0.980	0.980	0.981	0.982	0.983	0.983	0.984	0.984	0.985
84	0.957	0.959	0.960	0.962	0.965	0.966	0.968	0.970	0.971	0.972	0.974	0.974	0.975	0.976	0.977	0.978	0.979	0.979	0.979	0.980	0.981	0.981	0.982	0.982	0.983	0.983
86	0.954	0.956	0.956	0.959	0.961	0.964	0.966	0.967	0.968	0.969	0.971	0.971	0.972	0.973	0.975	0.976	0.977	0.977	0.977	0.978	0.979	0.980	0.980	0.981	0.981	0.982
88	0.950	0.952	0.953	0.955	0.958	0.961	0.963	0.965	0.966	0.967	0.969	0.969	0.970	0.971	0.973	0.974	0.975	0.976	0.976	0.977	0.978	0.978	0.979	0.979	0.980	0.980
90	0.946	0.949	0.949	0.952	0.955	0.958	0.960	0.962	0.963	0.964	0.967	0.967	0.968	0.969	0.971	0.972	0.973	0.974	0.974	0.975	0.976	0.977	0.977	0.978	0.978	0.979
92	0.942	0.945	0.946	0.949	0.952	0.955	0.957	0.959	0.960	0.962	0.964	0.965	0.966	0.967	0.969	0.970	0.971	0.972	0.972	0.973	0.974	0.975	0.975	0.976	0.977	0.977
94	0.938	0.941	0.942	0.946	0.949	0.952	0.954	0.957	0.958	0.959	0.962	0.962	0.964	0.965	0.967	0.968	0.969	0.970	0.970	0.971	0.972	0.973	0.974	0.975	0.975	0.976
96	0.935	0.938	0.939	0.942	0.946	0.949	0.952	0.954	0.955	0.957	0.959	0.960	0.961	0.963	0.965	0.966	0.967	0.968	0.968	0.970	0.971	0.972	0.972	0.973	0.974	0.975
98	0.931	0.934	0.935	0.939	0.943	0.946	0.949	0.952	0.953	0.954	0.957	0.957	0.959	0.961	0.963	0.964	0.965	0.966	0.966	0.968	0.969	0.970	0.971	0.972	0.972	0.973
100	0.927	0.930	0.932	0.936	0.940	0.943	0.946	0.949	0.950	0.952	0.954	0.955	0.957	0.959	0.961	0.962	0.963	0.964	0.964	0.966	0.967	0.968	0.969	0.970	0.971	0.972
105	0.917	0.920	0.923	0.927	0.931	0.935	0.939	0.943	0.943	0.946	0.949	0.949	0.951	0.954												
110	0.907	0.911	0.913	0.918	0.923	0.927	0.932	0.936	0.937	0.939	0.943	0.944	0.946	0.949												
115	0.897	0.902	0.904	0.909	0.915	0.920	0.925	0.930	0.930	0.933	0.937	0.938	0.940	0.944												
120	0.887	0.892	0.894	0.900	0.907	0.912	0.918	0.923	0.924	0.927	0.931	0.932	0.934	0.938												
125	0.876	0.881	0.884	0.890	0.898	0.903	0.909	0.916	0.916	0.920	0.925	0.927	0.928	0.933												
130	0.865	0.871	0.873	0.880	0.888	0.895	0.901	0.908	0.909	0.913	0.918	0.921	0.923	0.927												
135	0.854	0.861	0.863	0.871	0.879	0.887	0.894	0.901	0.902	0.907	0.912	0.914	0.916	0.921												
140	0.842	0.850	0.852	0.861	0.870	0.879	0.886	0.893	0.895	0.900	0.905	0.907	0.910	0.915												

EXAMPLE. Given the specific (60/60) 0.600 and temperature of measurement of 26° F. The volume correction factor to convert the volume at the measured temperature of 26° F to volume at 6°F is found by moving down the column headed 0.600 to intersect with the horizontal line from 26°F. The volume correction factor is 1.033.

Interchangeability of Various Gases

Interchangeability of gases is the use of a substitute gas for the gas usually distributed for domestic and industrial consumption without interfering with the operation of appliances used by the consumer.

The subject is complicated by many factors such as heating value, specific gravity, and composition of the various gases under consideration.

The present supply of natural gas has resulted in the distribution in many cities of gases of rather high heating values; in many cases, of straight natural gas having a heating value in excess of 1000 Btu per cu ft.

The American Gas Association has found that none of the formulae developed earlier for the interchangeability of mixed gases of lower heating value were applicable to the interchangeability of the higher heating value gases. New equations, which would take into consideration all factors affecting interchangeability, have been developed.

Interchangeability Factors

The interchangeability of higher heating-value gases is considered from three distinct viewpoints — the tendency of high heating value supplemental gases to —

1. Lift
2. Flashback
3. Produce yellow tips

The index of lifting interchangeability, I_L, is the result obtained from calculation of the lifting interchangeability equation:

$$I_L = \frac{K_a}{\frac{f_a}{f_s}\,\frac{a_s}{a_a}\left(K_s\text{-log}\,\frac{f_a}{f_s}\right)}$$

An empirical expression, I_F, denotes the tendency of burners to flashback as a result of interchanging a supplemental gas for natural gas.

$$I_F = \frac{K_s}{K_a}\,\frac{f_s}{f_a}\sqrt{\frac{h_s}{1000}}$$

Equation for I_Y takes into consideration changes in primary-air injection and yellow-tip limit resulting from substitution of one gas for another.

$$I_Y = \frac{f_s}{f_a}\,\frac{a_a}{a_s}\,\frac{Y_a}{Y_s}$$

Values for Equation Characters

In order to obtain values for the characters in these three equations, certain other equations must be employed, as follows:

Air theoretically required for complete combustion,

$$\text{per 100 Btu } a_a = \frac{100\,A_a}{h_a}$$

$$\text{Primary air factor } f_a = \frac{1000\sqrt{\ d_a}}{h_a}$$

$$\text{Lifting limit constant } K_a = \frac{F_a}{d_a}$$

$$\text{Yellow-tip limit } Y_a = \frac{100\,T_a}{A_a + 7E_a - 26.3O_{2a}}$$

Nomenclature for the equations:

- A = air theoretically required for complete combustion, cubic feet per foot of gas
- a = air theoretically required for complete combustion, cubic feet per 100 Btu of gas
- d = specific gravity (air = 1.0)
- E = total inerts in gas mixture, decimal volume
- F = lifting constant
- f = primary-air factor
- h = gross heating value, Btu per cubic foot
- I_F = index of flashback interchangeability
- I_L = index of lifting interchangeability
- I_Y = index of yellow-tip interchangeability
- K = lifting-limit constant
- O_2 = oxygen in gas mixture, decimal volume
- T = yellow-tip constant, cubic feet of air required to eliminate yellow tips per cubic foot of gas
- Y = yellow-tip limit, percent primary air
- Subscript a = adjustment gas
- Subscript s = substitute (or supplemental) gas.

Type of Natural Gas Distributed

The American Gas Association assumes that one of the three types of natural gas presented below would be the gas normally distributed.

		High Btu natural gas	High methane natural gas	High inert natural gas
Carbon dioxide	CO_2	0.5%	0.0%	0.5%
Methane	CH_4	83.0	94.5	71.4
Ethane	C_2H_6	16.0	0.0	14.0
Propane	C_3H_8	0.0	0.0	1.0
Nitrogen	N_2	0.5	5.5*	13.1
Btu per cu ft		1115	959	1000
Sp gr		0.64	0.56	0.69

* Inerts.

For any proposed adjustment, or substitute gas, all three indices must fall within certain numerical limits, which are shown in an accompanying table.

Interchangeability index	High-heating value nat. gas		High-methane nat. gas		High-inert nat. gas	
	Preferable	Objectionable	Preferable	Objectionable	Preferable	Objectionable
I_L	Under 1.0	Above 1.12	Under 1.0	Above 1.06	Under 1.0	Above 1.03
I_F	Under 1.18	Above 1.2	Under 1.18	Above 1.2	Under 1.18	Above 1.2
I_Y	Above 1.0	Under 0.7	Above 1.0	Under 0.8	Above 1.0	Under 0.9

AGA "Index C" Method

The American Gas Association "Index C' is a criteria developed for the interchangeability of gases with heating values below 700 Btu per cu ft. If the supplemental gas has a "C" index in the range 0.85 to 1.15, it is considered that it could replace the base gas and maintain satisfactory appliance performance.

The equation is —

$$C = \frac{h_s}{h_a}\,\frac{A_s}{A_a}\,\frac{d_a}{d_s} + (K_a - K_s)$$

EXAMPLE: Given the specific (60/60) 0.600 and temperature 0 to intersect with the horizontal line from 26°F. The volume correction factor volume at 6°F is found by moving down the column headed 0.600 to intersect with the horizontal line from 26°F.

where,

C = index of interchangeability
a = subscript denoting adjustment gas
s = subscript denoting substitute gas
h = gross heating value, Btu per cubic foot
A = air theoretically required for complete combustion, cubic feet per cubic foot of gas
d = specific gravity of gas (air = 1.0)
$K = \frac{hA}{5000\ E\ F}$ in which
E = the heat capacity of the theoretical products of combustion (from one cubic foot of gas) per degree F between 60 F and 1600 F, in Btu E is equal to 0.029 VCO_2 + 0.0023 VH_20 + 0.0189VN_2 where V is the volume in cubic feet of each product (as indicated by the subscripts) formed by the combustion of one cubic foot of gas with the air theoretically required for complete combustion. The values 0.029, 0.0023 and 0.0189 are, respectively, the heat capacities per degree F of CO_2, H_2O, and N_2, between 60 F and 1600 F in Btu per cubic foot.
F = Summation of the products of the mole fractions and some constant for each combustible constituent in the gas.

Disadvantages of "Index C" Equation

Several disadvantages are cited against the use of "Index C" in some cases.

1. It does not apply for mixtures in which the percentage of inerts exceeds the free-hydrogen content.

2. It is not generally applicable for mixtures involving adjustment and substitute gases of widely differing heating value or chemical composition unless the fraction of such radically differing gas in the substitute mixture does not exceed about 12 percent. Thus the formula does not hold for such substitute mixtures as propane or butane and air, of natural gas inert mixtures, etc.

3. The formula does not usually apply in cases involving the use of large amounts of oil gases as substitutes for natural gas.

4. It is not fully applicable for gases of heating values higher than 800 Btu per cu ft since the equation has no factors which predict the occurrence of yellow tips or lifting.

In 1946, the American Gas Association started a new series of tests on the interchangeability of gases of relatively low heating value.

Knoy Formula

Several simple formulas have been proposed for use in determining the interchangeability of gases. The most well known is the Knoy formula, which is as follows:

$$C = \frac{H - 180}{\sqrt{G}}$$

C = a constant
H = heating value of gas, Btu per cubic foot
G = specific gravity of gas (air =1)
180 = the heating value in Btu per cubic foot of the primary air-gas mixture which is assumed to be the proper adjustment for domestic burners.

The theory of this formula is that gases which have the same "C" factor are interchangeable. Actually the normal flexibility of most domestic-appliance burners allows some variation in the "C" factor. This deviation will not usually exceed 10 percent up or down from the "C" factor of the adjustment gas. "C" factor for substitute gases which are above that of the adjustment gas indicate softer types of flames, while harder flames are indicated if the "C" factor is found to be below that for the adjustment gas.

It has been stated that the results obtained by the use of the Knoy formula may be misleading if the chemical composition of the substitute gas does not correspond to that of the adjustment gas, and as a rule, limit mixtures defined by means of AGA Index C are considered to be more reliable than those indicated by the Knoy formula.

New Test Burners Devised

Many test burners have been devised to assist in evaluating the interchangeability of gases by observation of flame characteristics. At the present time there is no available instrument which can be applied in all cases to evaluate the gas quality. In approaching a problem involving interchangeability of gas, it is desirable to make calculations first, using the interchangeability equations and then burn the prepared mixtures in appliances having burners characteristic of those used in the community to be certain that the substitute gases will actually burn satisfactorily.

It is desirable that gas companies keep a control burner at the inlet and outlet of their gas-storage holders in order that they may, at all times, have a knowledge of the burning characteristics of the gas being produced and sent out.

Oil Gas Not Complete Replacement

It can be stated that high Btu oil gas, as now known, cannot be used as complete replacement for natural gas. However, some 30 to 60 percent of these high Btu oil gases can be used in admixture with natural gas without excessive complaints from the consumers of the gas.

It must be pointed out that in some cases substitute gases appear to be entirely satisfactory from the standpoint of visual flame characteristics, but the products of combustion may contain dangerous quantities of carbon monoxide.

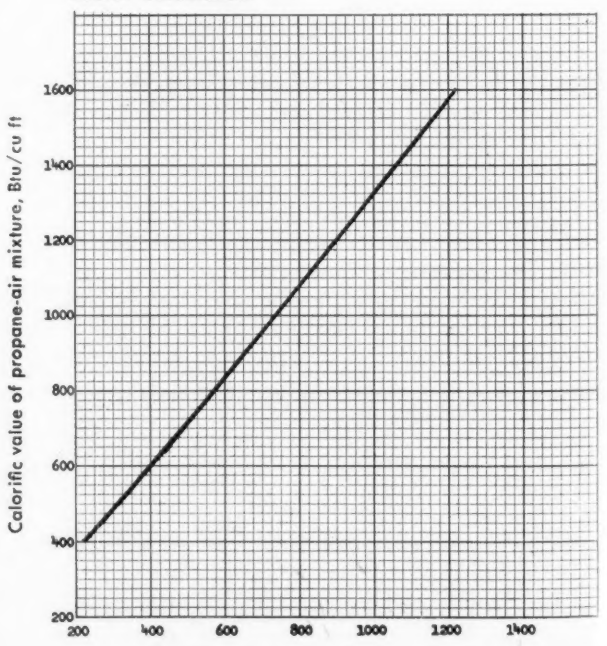
Determination of Proper Btu Value of Propane-Air Gas to be Used as a Substitute Gas

Procedure for calculating proper propane-air gas:

1) Determine "C" factor original gas from the following formula:

$$C = \frac{\text{Btu} - 180}{\sqrt{\text{Sp. Gr.}}}$$

2) Read chart for proper propane-air gas for "C" factor calculated



"C" Factor, Knoy's Formula, 180 Btu/ cu ft air-gas mixture in burner head.

GAS COMBUSTION CONSTANTS

No.	Gas	Formula	Lbs per cu. ft.	Cu. ft. per lb	Sp. gr. Air = 1.000	Heat of combustion: Btu per cu. ft. Gross	Heat of combustion: Btu per cu. ft. Net	Heat of combustion: Btu per lb Gross	Heat of combustion: Btu per lb Net	Cu. ft per cu. ft. of combustible: Required for combustion O_2	N_2	Air	Flue products CO_2	H_2O	N_2	Lbs. per lb. of combustible: Required for combustion O_2	N_2	Air	Flue products CO_2	H_2O	N_2
1	Carbon	C	.....	.....	.....	.....	.....	14,140†	14,140†	....	.....	.....	.....	...	.....	2.667	8.873	11.540	3.667	.....	8.873
2	Hydrogen	H_2	0.005327	187.723	0.06959	323.5	275.1	61,100	51,643	0.5	1.882	2.382	...	1.0	1.882	7.939	26.414	34.353	.....	8.939	26.414
3	Oxygen	O_2	0.08461	11.819	1.1053	.....	.....	.....	.....	....	.....	.....	...	...	.....	.....	.....	.....	.....	.....	.....
4	Nitrogen (atmos.)	N_2	0.07439*	13.443*	0.9718*	.....	.....	.....	.....	....	.....	.....	...	...	.....	.....	.....	.....	.....	.....	.....
5	Carbon monoxide	CO	0.07404	13.506	0.9672	323.5**	323.5	4,369	4,369	0.5	1.882	2.382	1.0	...	1.882	0.571	1.900	2.471	1.571	.....	1.900
6	Carbon dioxide	CO_2	0.1170	8.548	1.5282	.....	.....	.....	.....	....	.....	.....	...	...	.....	.....	.....	.....	.....	.....	.....
Paraffin series C_nH_{2n+2}																					
7	Methane	CH_4	0.04243	23.565	0.5543	101 7‡	913.8	23,912	21,533	2.0	7.528	9.528	1.0	2.0	7.528	3.992	13.282	17.274	2.745	2.248	13.282
8	Ethane	C_2H_6	0.08029*	12.455*	1.04882*	178	1631	22,215	20,312	3.5	13.175	16.675	2.0	3.0	13.175	3.728	12.404	16.132	2.929	1.799	12.404
9	Propane	C_3H_8	0.1196*	8.365*	1.5617*	2572	2371	21,564	19,834	5.0	18.821	23.821	3.0	4.0	18.821	3.631	12.081	15.712	2.996	1.635	12.081
10	Iso-butane	C_4H_{10}	0.1582*	6.321*	2.06654*	3251	2999	21,247	19,606	6.5	24.467	30.967	4.0	5.0	24.467	3.581	11.914	15.495	3.030	1.551	11.914
11	n-Butane	C_4H_{10}	0.1582*	6.321*	2.06654*	3353	3102	21,247	19,606	6.5	24.467	30.967	4.0	5.0	24.467	3.581	11.914	15.495	3.030	1.551	11.914
12	n-Pentane	C_5H_{12}	0.1904*	5.252*	2.4872*	3981	3679	20,908	19,322	8.0	30.114	38.114	5.0	6.0	30.114	3.551	11.815	15.366	3.052	1.499	11.815
13	n-Hexane	C_6H_{14}	0.2274*	4.398*	2.9704*	4667	4315	20,526	18,976	9.5	35.760	45.260	6.0	7.0	35.760	3.530	11.745	15.275	3.067	1.465	11.745
Olefin series C_nH_{2n}																					
14	Ethylene	C_2H_4	0.07456	13.412	0.9740	1631	1530	21,884	20,525	3.0	11.293	14.293	2.0	2.0	11.293	3.425	11.395	14.820	3.139	1.285	11.395
15	Propylene	C_3H_6	0.1110*	9.007*	1.4504*	2336	2185	21,042	19,683	4.5	16.939	21.439	3.0	3.0	16.939	3.425	11.395	14.820	3.139	1.285	11.395
16	Butylene	C_4H_8	0.1480*	6.756*	1.9336*	3135	2884	20,840	19,481	6.0	22.585	28.585	4.0	4.0	22.585	3.425	11.395	14.820	3.139	1.285	11.395
17	Acetylene	C_2H_2	0.06971	14.344	0.9107	1503	1453	21,572	20,840	2.5	9.411	11.911	2.0	1.0	9.411	3.075	10.231	13.306	3.383	0.692	10.231
Aromatic series C_nH_{2n-6}																					
18	Benzene	C_6H_6	0.2060*	4.852*	2.6920*	3741	3590	18,150	17,418	7.5	28.232	35.732	6.0	3.0	28.232	3.075	10.231	13.306	3.383	0.692	10.231
19	Toluene	C_7H_8	0.2431*	4.113*	3.1760*	4408	4206	18,129	17,301	9.0	33.878	32.878	7.0	4.0	33.878	3.128	10.407	13.535	3.346	0.783	10.407
20	Xylene	C_8H_{10}	.....	.....	.....	5155	.....	18,410	.....	10.5	39.524	50.024	8.0	5.0	39.524	3.168	10.540	13.708	3.318	0.849	10.540
21	Naphthalene	$C_{10}H_8$	.....	.....	.....	5859	.....	17,298		12.0	45.170	57.170	10.0	4.0	45.170	2.999	9.978	12.977	3.436	0.563	9.978
Miscellaneous gases																					
22	Ammonia	NH_3	0.04563*	21.914*	0.5961	433	.....	9,598	.....	....	.....	.....	SO_2= ...	...	.....	.....	.....	.....	SO_2= ...	.....	.....
23	Hydrogen sulfide	H_2S	0.09109*	10.979*	1.1898*	672	.....	7,479	.....	1.5	5.646	7.146	1.0	1.0	5.646	1.408	4.685	6.093	1.880	0.529	4.685
24	Sulfur dioxide	SO_2	0.1733	5.770	2.264	.....	.....	.....	.....	....	.....	.....	...	...	.....	.....	.....	.....	.....	.....	.....
25	Water vapor	H_2O	0.04758*	21.017*	0.6215*	.....	.....	.....	.....	....	.....	.....	...	...	.....	.....	.....	.....	.....	.....	.....
26	Air	....	0.07655	13.063	1.0000	.....	.....	.....	.....	....	.....	.....	...	...	.....	.....	.....	.....	.....	.....	.....

NOTES:

All gas volumes corrected to 60° F. and 30" Hg dry.

* Densities calculated from values given in grams per liter at 0° C. and 760 mm. in the International Critical Tables for the known deviations from the gas laws. Where the coefficient of expansion was not available, the assumed value was taken as 0.0037 per ° C. Compare this with 0.003662 which is the coefficient for a perfect gas. Where no densities were available the volume of the mol was taken as 22.4115 liters. The asterisk (*) denotes that either the density or the coefficient of expansion has been assumed. The heats of combustion have been obtained by reviewing the experimental and critical data available. The 1929 A.G.A. Chemical Committee examined and approved the selection for the Gas Chemists Handbook. As far as possible the net heat of combustion per lb is the base figure from which all others were calculated. The data, given in mean Btu per lb (1/180th of the heat per lb of water from 32° F to 212° F.) have been compiled largely from Bureau of Standards publications, Bulletins of the University of Illinois Engineering Experimental Station, International Critical Tables, etc.

† Carbon — Roth and Naesser, Z. für Elektrochemie 31:461 (1925). White and black diamonds.

‡ Methane — Research Paper 260, Bureau of Standards (January 1931) corrected. C_8H_{10}, $C_{10}H_8$, H_2S and NH_3 from 1929 A.G.A. Gas Chemists Handbook.

For precise calculations with gases saturated with water vapor, 1.73% of the Btu value must be deducted to correct for the presence of water vapor.

Gross heating values are calculated from the net by allowing for the heat of vaporization of water at 60° F., amounting to 50.3 Btu per cu ft of water vapor or 1057.8 Btu per lb.

** Rossini in Bureau of Standards Research Paper 260 finds the heat of combustion of carbon monoxide to be 321.7 Btu per cu ft. Although not adopted for this edition, there is reason to believe that Rossini's value is the most accurate now available.

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RAPID SURVEY METHOD OF GAS REQUIREMENTS AND COSTS

In many of its phases, the selling of gas heat is very much like other specialty selling where the cost of the item or of the service to be furnished depends on the particular conditions surrounding the individual prospect.

The estimate of annual operating cost for one prospect may figure only $50.00, whereas that for another would be $500.00. When the one in the $500.00 class first makes inquiry about gas heat, his interest may be based on thinking in terms of $50.00. Likewise, the one who is in the $50.00 class may not have exhibited any interest, because he was thinking in terms of $500.00.

A method, therefore, whereby the salesman in the field can figure the estimate with reasonable accuracy and in just a few minutes time, is of great assistance in qualifying prospects. Such a method can be made sufficiently accurate to justify the salesman in attempting to close the order on the basis of the rapid survey method. If successful, then before the installation is made, his engineering department, if it so desires, can make a more elaborate survey and estimate. This can be done as if it is merely a part of the usual installation routine, so that the customer's confidence in the salesman is not affected in any way. Should this detailed survey show any glaring discrepancies, the matter can be taken up with the customer in advance of installation, so that no one will be unfavorably affected.

To show how such a rapid survey can be developed, the starting point is the formula used by heating engineers in figuring the seasonal operating cost to take care of any given area of wall, ceiling or floor.

FORMULA

(Heat loss in Btu per Hour)

$$\frac{\text{Area} \times \text{Heat Transfer Coefficient} \times \text{Temp. Rise} \times \text{Hrs. Heated} \times \text{Degree Days} \times \text{Gas Rate in Cts. Per M Cu Ft}}{\text{Temperature Rise} \times \text{Btu Heat Content} \times \text{Efficiency} \times 1000 \times 100} = \text{Season's Operating Cost in Dollars for that Area}$$

While there are many factors in the long formula, examination will show that for any certain type of construction practically all of them are constant for any given territory. The coefficient of any certain material is always the same — the temperature rise is nearly always figured at 70 degrees — the temperature differential between basement and house interior at 20 degrees — and between interior and attic at 35 degrees — the number of hours per day is always 24 — the number of degree days for any given territory is regarded as a constant — the gas rate and the Btu content are constant for a territory. While the efficiency factor may vary slightly with different types of equipment, an average efficiency of 75 per cent can be used for reasonably accurate results. This means that all of the factors in that long formula can be condensed for any territory into one single factor for each type of construction. Then it is simply a case of multiplying the given area by one factor instead of working out the entire formula shown above.

Another point of simplification is to measure the house as a whole rather than to measure the individual rooms. It is simple for the salesman to compute the volume by measuring the width, height, and depth of the house. Naturally, if the prospect states that certain rooms have not been heating satisfactorily with the old furnace equipment, then individual rooms should be measured and duct work or radiation checked. Just as in the case of figuring the heat loss through the walls, ceiling, or floor, the volume can be multiplied by a single constant to determine the seasonal operating cost for offsetting loss by infiltration.

With the above thought in mind, a single factor, which for purposes of clarity in explaining is called factor "F", has been worked out for the most commonly encountered types of construction. To convert this factor "F" into the correct constant for any territory, it is only necessary to multiply it by a certain multiplier, designated as "M," with "M" being determined as follows:

$$M = \frac{\text{Local Degree Days} \times \text{Average Local Heating Rate in Cents per M/Cu Ft}}{\text{Btu Content of Local Gas}}$$

or

$$M = \frac{\text{Local Degree Days} \times \text{Rate per Therm in Cents}}{100{,}000}$$

The following table gives the factor "F" for the most unusual types of building constructions. Figure local multiplier, "M," as outlined above, multiply M by F and then it is possible to fill in this table with the local constant which will be used in figuring the seasonal operating cost to offset the heat loss through any given area of wall, ceiling, or floor.

Type of Material	Factor "F"	Multiplier "M"	Final constant
Single glass	0.000352	.....	.....
Double glass	0.000143	.....	.....
Walls:			
8″ Brick, sheathing, stud, L&P	0.000085	.....	.....
Stucco, wood, and plaster	0.000099	.....	.....
Stone, tile, furred, L&P	0.000077	.....	.....
Clapboards, studding, L&P	0.000080	.....	.....
Floors:			
Wood floor. No. ceiling below	0.000042	.....	.....
Double floor. L&P below	0.000022	.....	.....
Ceilings:			
Plaster board and plaster	0.000098	.....	.....
Rigid insulation and plaster	0.000056	.....	.....
Roofs:			
Tile or slate on wood	0.000179	.....	.....
Shingles, sheathing, stud, L&P	0.000102	.....	.....
Volume:			
To offset air infiltration:			
One air change per hour	0.0000058	.....	.....
One and one-half air changes	0.0000087	.....	.....
Two air changes per hour	0.0000116	.....	.....

NOTE: For any wall construction not listed above which may be found to be common in the locality, the factor "F" may be obtained by:
Coefficient of Transmission × 0.00032 = F

After the above final constants for the territory have been worked out, it is recommended that they be printed on a survey card arranged along the lines of the one reproduced here. The reverse side of the card can carry the usual general information as to the prospect's name and address, date of survey, and the like.

With permission, from Surface Combustion Corp.

SUGGESTED FORM FOR RAPID SURVEY METHOD

Area sq. ft.	Material	Local factor	Operating cost per season
....	Glass: Single	....	$.....
....	Glass: Double	....	.....
....	Walls (net): 8″ brick	....	.....
....	Stucco, tile and plaster	....	.....
....	Stone, tile, furred, L&P	....	.....
....	Clapboards, studding, L&P	....	.....
....	.....	....	.....
....	Floors: Wood floor, no ceil. below	....	.....
....	Double floor: L&P below joists	....	.....
....	.....	....	.....
....	Roofs: Tile or slate on wood	....	.....
....	Shingles, sheathing, studding, L&P	....	.....
....	.....	....	.....
Cu. ft.	Volume		
....	Infiltration: 1 air change per hr	....	.....
....	1½ air changes per hr	....	.....
....	2 air changes per hr	....	.....
	.....		
	Total operating cost per season	....	$.....

If Btu heat loss per hour is desired, use formula $= \frac{218{,}750 \times \text{Season's Cost}}{M}$

HEAT DELIVERY OF SPACE HEATING EQUIPMENT

STEAM: 1 sq ft cast iron radiation = 240 Btu/hr (2 Lb steam 70 F room temp)

HOT WATER: 1 sq ft cast iron radiation = 150 Btu/hr 70 F room temp

FORCED HOT WATER: 1 sq ft cast iron radiation = 200 Btu/hr (70 F room temp)

GRAVITY WARM AIR: 1 sq in. of basement duct (175 F register temp)

= 110 Btu/hr on first floor

= 166 Btu/hr on second floor

= 200 Btu/hr on third floor

FORCED WARM AIR: *The following formula gives the heat delivered at the register of a forced warm air heating system.*

$$H = A \times V \times 60 \times W \times S \times (t_d - t_r)$$

Symbols:

H = Heat delivered in Btu per hour.

A = Net area of discharge register in sq ft.

V = Velocity of air leaving register in ft per minute.

W = Weight of air at temperature t_d in pounds per cubic foot.

S = Specific heat of air in Btu per pound per degree F at temperature t_d.

t_d = Temperature in degrees F of air leaving register.

t_r = Temperature in degrees F of space being heated.

With permission, "Surface Combustion Industrial Heating Handbook."

EXAMPLE

CONDITIONS

Assume the following conditions for the computation of the seasonal operating cost in a home:

Two and one-half story residence

Walls: 8″ brick, lath and plaster inside over sheathing

Ceilings second floor: Plaster board and plaster

No flooring in attic

Floors: Frame construction, single thickness

Single glass windows

Air changes per hour: 1

Gross wall area:
- First floor, 1300 sq ft
- Second floor, 1150 sq ft

Glass area:
- Windows and doors
- First floor, 190 sq ft
- Second floor, 130 sq ft

Area second floor ceiling: 1010 sq ft

Area first floor: 1010 sq ft

Cubical contents:
- First floor, 9100 cu ft
- Second floor, 8700 cu ft
- Degree days 6000
- Gas rate 40c/M cu ft
- Btu content 530

PRELIMINARY

$$M = \frac{6000 \times 40}{530} = 453$$

Final constant for glass area	=	.000352 × 453	= .159
Final constant for wall area	=	.000085 × 453	= .0385
Final constant for floor area	=	.000042 × 453	= .019
Final constant for ceiling area	=	.000098 × 453	= .044
Final constant for infiltration	=	.0000058 × 453	= .0026

SOLUTION

320 square feet glass area	×	.159	=	$ 50.88
2,130 square feet wall area	×	.0385	=	82.00
1,010 square feet floor area	×	.019	=	19.19
1,010 square feet ceiling area	×	.044	=	44.44
17,800 cubic feet infiltration	×	.0026	=	46.28
				$242.79

Estimating Water Heater Requirements

Selection of heater and storage tank for hot water depends on maximum daily demand and maximum hourly demand. Generally, two-thirds of the total daily water consumption is hot water. A design value of 20 to 30 gal per person can be assumed for private homes; hot water usage, though, also depends on the number of rooms and number of bathrooms in the home.

To estimate the required size for a hot water storage tank, and heating (or recovery) capacity required, it is necessary to know the total quantity of water to be heated and maximum amount to be used in any one hour period, as well as duration of the peak load.

Reasonably uniform storage capacity requirements usually exist for residences, apartment buildings, hotels, motels, and similar buildings and are smaller than those needed for factories, office buildings, and schools, where the entire day's usage of hot water occurs in a relatively short period.

Where usage is reasonably uniform, heating capacity must be proportionately greater than with intermittent usage where peak demands are so spaced to allow water in the storage tank to be brought up to the desired temperature. As a rule, large storage capacity is preferred to keep the size of heater or boiler as small as possible.

In estimating storage tank capacity, it should be noted that only about 75 percent of the volume is available because, by the time this amount is drawn off, incoming cold water has cooled the remainder to where it is no longer hot water.

Two methods are commonly used to estimate hot water requirements of a building: (1) by number of people, and (2) by number of plumbing fixtures installed. Table 1 provides data for estimates where the number of people using hot water can be reasonably estimated. Data on self-service laundries and restaurants is also included. Table 2 provides data for sizing water heating equipment from the number of fixtures. Minimum hot water requirements for modern homes are given in Table 3. Table 4 provides data on recovery capacity of water heaters.

The following examples illustrate use of the tables to estimate hot water requirements:

Example 1: Determine size of heater and storage tank capacity for residence of six people.

Solution: From Table 1, daily requirements = $6 \times 40 = 240$ gal.

Maximum hourly demand = $240 \times 0.143 = 34.3$ gal.

Heater should have storage capacity of $240 \times 0.200 = 48$ gal.

Heater should have heating capacity of $240 \times 0.143 = 34.3$ gal/hr.

Storage and heating capacity can be varied by increasing and decreasing one over the other. Such a condition can be seen in the next example.

Example 2: Determine (a) heater capacity for apartment building of 100 people that has storage tank with capacity of 500 gal, and (b) what heater capacity would be needed if storage tank was changed to 1000 gal capacity?

Solution: From Table 1, daily requirements = $100 \times 40 = 4000$ gal.

Maximum hourly demand = $4000 \times 0.143 = 570$ gal.

Duration of peak load = 4 hours.

Peak load requirements = $4 \times 570 = 2280$ gal.

If a 500-gal storage tank is used, hot water from tank = $0.75 \times 500 = 375$ gal.

Water to be heated = $2280 - 375 = 1905$ gal.

Heating capacity per hour = $1905 \div 4 = 476$ gal.

If a 1000-gal storage tank is used, required heating capacity would be

$$\frac{2280 - (1000 \times 0.75)}{4} = 383 \text{ gal.}$$

TABLE 1. Estimated Hot Water Demand Characteristics For Various Types of Buildings and Businesses.

Type of Building	Hot Water Required (at 140 F)	Max. Hourly Demand in Relation to Day's Use	Duration of Peak Load Hours	Storage Capacity in Relation to Day's Use	Heating Capacity in Relation to Day's Use
Residences, motels, apartments, hotels, etc.	40 gal per person per day	0.143	4	0.200	0.143
Office buildings	2 gal per person per day	0.200	2	0.200	0.167
Factory buildings	5 gal per person per day	0.333	1	0.400	0.125
Self-Service Laundries—Hot water requirements per machine installed—		{15 gal storage heating capacity 25 gal heating capacity (at 100 F rise)			

RESTAURANTS*		Type of Dishwashing	Type of Meals Served	Storage Capacity, gal per Meal	Heating Capacity, gal per Meal
Restaurants—(24-hour)	Hot water requirements per meal served	Hand	{low price med.-price high-price	0.100 0.150 0.200	0.050 0.075 0.100
		Machine	{low-price med.-price high-price	0.150 0.250 0.450	0.075 0.125 0.225
Restaurants—(two-meals)	Hot water requirements per meal served	Hand	{low-price med.-price high-price	0.200 0.300 0.400	0.050 0.075 0.100
		Machine	{low-price med.-price high-price	0.300 0.500 0.900	0.075 0.125 0.225
Restaurants—(one-meal)	Hot water requirements per meal served	Hand	{low-price med.-price high-price	0.450 0.670 0.900	0.050 0.075 0.100
		Machine	{low-price med.-price high-price	0.670 1.125 2.025	0.075 0.125 0.225

*Figures cited are for total requirements. Water temperature is to be maintained at 140 F in storage tank. Separate means required for obtaining 180 F sterilizing water. For hand-washing, quantity of 180 F water determined from capacity of sink used. For machine-washing, 180 F water requirements determined from rating of dish machine. See text for additional information on dishwashing machines.

In using Table 2 to determine size of equipment from number of fixtures, the following steps are observed:

1. Multiply total number of each fixture by demand per fixture for type of building. Addition of these quantities gives *possible maximum demand.*
2. *Probable maximum demand* is found by multiplying the total quantity for all fixtures by the *demand factor* in line 11 of Table 2.
3. Heater or coil capacity should be equal to this *probable maximum demand.*
4. Storage tank capacity should be equal to *probable maximum demand* multiplied by the *storage capacity factor* in line 12.

Example 3: Determine heater and storage tank size for apartment building from number of plumbing fixtures installed (from Table 2):

Solution:

40 lavatories	× 2 =	80 gal per hr
20 bathtubs	× 20 =	400 gal per hr
20 showers	× 75 =	1500 gal per hr
40 kitchen sinks	× 10 =	400 gal per hr
10 laundry tubs	× 30 =	300 gal per hr

Possible maximum demand = 2680 gal per hr

Probable max. demand = 2680 × 0.30 = 804 gal per hr

Heater or coil capacity = 804 gal per hr

Storage tank capacity = 804 × 1.25 = 1005 gal per hr

180 F Hot Water. In private homes, water temperature of 140 F is reasonable for dishwashing; in public places, however, sanitation regulations call for 180 F water. Most dishwashing machines available today require 180 F water; the amount needed may be determined by the following method suggested by the A.G.A.:

1. Determine total number of dishes per day as follows. Multiply total meals times number of dishes used per meal (6 dishes for low price restaurants, 8 for medium-price, and 10 for high-price).
2. Find number of racks per day = $\frac{\text{total no. of dishes}}{\text{avg dishes per rack}}$
3. Multiply number racks per day by gallons of 180 F water required (use 1.5-gal for single tank machine, 0.75-gal for two tank machines).
   This gives total gal of 180 F water needed per day for rinse sprays.
4. Multiply number of meal periods per day (1, 2, or 3) by dishwashing machine tank capacity in gallons; this gives gallons of 180 F water per day necessary to fill tanks.
5. Add values in (3) and (4) to obtain total gallons of 180 F water required per day.

For purposes other than dishwashing, a considerable amount of 140 F water is also used. Table 1 gives total hot water storage and heating capacities required per meal for three types of restaurants in the three meal price ranges. Average hot water (140 F) utilization per meal is 0.9-gal for low-price restaurants, 1.2-gal for medium-price restaurants, and 1.5-gal for high-price restaurants. To this must be added the 180 F water requirements.

TABLE 2. Hot Water Demand per Fixture for Various Types of Buildings.
(Gal per hr per fixture at 140 F final temperature)

	Apartment House	Club	Gymnasium	Hospital	Hotel	Industrial Plant	Office Bldg	Private Residence	School	YMCA-YWCA
1. Basins, private lavatory	2	2	2	2	2	2	2	2	2	2
2. Basins, public lavatory	4	6	8	6	8	12	6	—	15	8
3. Bathtubs	20	20	30	20	20	30	—	20	—	30
4. Dishwashers	15	50–150	—	50–150	50–200	50–150	—	15	50–150	50–150
5. Foot basins	3	3	12	3	3	12	—	3	3	12
6. Kitchen sink	10	20	—	20	20	20	—	10	10	20
7. Laundry, stationary tub	30	30	—	30	30	30	—	30	—	30
8. Pantry sink	5	10	—	10	10	—	—	5	10	10
9. Showers	75	150	225	75	75	225	—	75	225	225
10. Slop sink	20	20	—	20	30	20	15	15	20	20
11. DEMAND FACTOR	0.30	0.30	0.40	0.25	0.25	0.40	0.30	0.30	0.40	0.40
12. STORAGE CAPACITY FACTOR*	1.25	0.90	1.00	0.60	0.80	1.00	2.00	0.70	1.00	1.00

*Ratio of storage tank capacity to probable maximum demand per hour.

TABLE 3: Hot water requirements of Modern Homes

Activity	*Hot Water Requirements, gal.*
Personal Use	
Shower bath	10–15
Tub bath	10–15
Baby's bath	3– 5
Hand and face washing daily	1– 2
Shampooing	5– 8
Shaving	1– 2
Laundering	
Automatic clothes washer, per load per cycle	18–35
Non-automatic washer, per washer filling, plus two rinses	20–35
Hand washing, lingerie	2– 3
Dishwashing	
Automatic dishwasher, per load	3–10
Hand dishwashing, per meal	3– 6
Rinsing, per meal	2– 3
Cleaning	
Floor mopping, per room	2– 3
Floor washing, per room	3– 5
Window washing, avg. room	2– 5
Woodwork washing, per room	1– 3
Venetian blind washing, avg. home	10–20
Cleaning refrigerator or range	2– 5
Washing automobile	10–20
Shampooing rug, avg. size	3– 5

TABLE 4. Recovery Rates of Rated Water Heaters at Temperature Rises Other Than 60 F, in Gal Per Hour Recovered to 140 F.

Gal per hr Rating (A.G.A.) at 60 F rise	Corresponding gal per hr rating at 140 F delivery with rise of					
	70 F	80 F	90 F	100 F	110 F	120 F
20	17.1	15	13.4	12	10.5	10
30	25.7	22.5	20	18	16.4	15
40	34.3	30	26.7	24	21.8	20
50	42.8	37.5	33.4	30	27.3	25
60	51.5	45	40	36	32.7	30
70	60	52.5	46.7	42	38.2	35
80	68.5	60	53.3	48	43.6	40
90	77.1	67.5	60	54	49.1	45
100	85.7	75	66.8	60	54.5	50

When recovery capacities different from those listed above are needed, use the following formula:

$$C = \frac{60\ R}{(T_1 - T_2)}$$

Where C = Corresponding recovery rate in gal per hr.
R = AGA rating in gal per hour with 60 F rise.
T_1 = Outlet temperature desired.
T_2 = Inlet temperature of water to be heated.

Example: Find recovery rate of water heater with 50-gal A.G.A recovery rating if inlet temperature is 45 F and outlet temperature desired is 140 F.

Solution:

$$C = \frac{60 \times 50}{(140 - 45)} = \frac{95}{3000} = 31.5 \text{ gal per hr.}$$

Venting of Gas Appliances

EDITOR'S NOTE: This section is extracted from *ASA Z21.30-1959, American Standard for the Installation of Gas Appliances and Gas Piping,* sponsored by the American Gas Association, and approved by the American Standards Association, July 21, 1959. It is reproduced here by permission of the copyright owner, American Gas Association. This extract is comprised of Section 5 of that standard. Additional venting information is given in this GAS HANDBOOK in the sections on *Installation of Gas Piping and Equipment on Industrial and Commercial Premises.*

5.1. Requirements for Venting

5.1.1. Appliances Required to Be Vented: Appliances of the following types shall be vent connected or provided with other means for removing the flue gases to the outside atmosphere.

a. Central heating appliances, including steam and hot water boilers, warm air furnaces, floor furnaces and vented recessed heaters.
b. Unit heaters and duct furnaces.
c. Incinerators.
d. Water heaters with inputs over 5000 Btu per hour, except automatically controlled instantaneous water heaters which supply water to a single faucet which is attached to and made a part of the appliance (see 4.5.1).
e. Built-in domestic cooking units listed and marked only as vented units.
f. Room heaters listed only for vented use. Room heaters listed as "vented and unvented" units may be installed either vented or unvented (see 4.6.1 and 4.6.2).
g. Appliances equipped with gas conversion burners.
h. Other listed appliances which have draft hoods supplied by the appliance manufacturer.
i. Unlisted appliances, except as provided under 5.1.2-j.

5.1.2. Appliances Not Required to Be Vented:

a. Listed ranges.
b. Built-in domestic cooking units listed and marked as unvented units.
c. Listed hot plates and listed laundry stoves.
d. Listed domestic clothes dryers.
*e. Listed water heaters with inputs not over 5000 Btu per hr.
*f. Listed refrigerators.
*g. Counter appliances.
*h. Room heaters listed for unvented use (see 4.6.1 and 4.6.2).
*i. Other appliances listed for unvented use and not provided with flue collars.
*j. Specialized equipment of limited input such as laboratory burners or gas lights.

When any or all of the appliances starred above (*) are installed so that the aggregate input rating exceeds 30 Btu per hour per cu ft of room or space in which they are installed, one or more of them shall be vent connected or provided with an approved means for removing the vent gases to the outside atmosphere so that the aggregate input rating of the remaining unvented appliances does not exceed the 30 Btu per cu ft figure. When the room or space in which they are installed is directly connected to another room or space by a doorway, archway, or other opening of comparable size, which cannot be closed, the volume of such adjacent room or space may be included in the calculations.

5.2. Methods of Venting

5.2.1. Gas vent or chimney systems shall be engineered and constructed so as to develop a positive flow adequate to remove all flue gases to the outside atmosphere.

5.2.2. All gas appliances required to be vented shall be connected to a gas vent or chimney except as provided in 5.6.

5.2.3. Chimneys shall be used for venting the following types of appliances:

a. Incinerators, except as provided in 5.2.7.
b. Appliances which may be converted readily to the use of solid or liquid fuels.
c. Combination gas-oil burning appliances.
d. Appliances listed for use with chimneys only.

5.2.4. Type B gas vents may be used to vent listed gas appliances except as provided in 5.2.3, 5.2.5, and 5.6.1.

5.2.5. Type B-W gas vents shall be used with listed vented recessed heaters when installed within combustible 2 x 4 wall construction. (see 4.8.1.)

5.2.6. Type C gas vents may be used to vent gas burning appliances, except as provided in 5.2.3 and 5.2.5.

5.2.7. Metal pipe not less than No. 20 U. S. Standard gage galvanized iron or other equivalent noncombustible, corrosion resistant material may be used for venting incinerators installed in locations such as open sheds, breezeways, or carports, provided the metal pipe is exposed and readily examinable for its full length and suitable clearances are maintained (see Table 11).

5.3. Installation Requirements for Gas Vents and Chimneys

5.3.1. General: Sections 5.3 through 5.5 apply only to natural draft venting.

5.3.2. Gas Vents:

a. Listed Type B and listed Type B-W gas vents shall be installed in accordance with their listings and the manufacturer's instructions.

b. Type C gas vents shall be used only for runs directly from the space in which the appliance is located through the roof or exterior wall to the outer air. Such gas vents shall not originate in any unoccupied attic or concealed space, and shall not pass through any attic, inside wall, concealed space, nor through any floor.

When a Type C gas vent passes through an exterior wall constructed of combustible material it shall be guarded at the point of passage by a method described in 5.5.14.

When a Type C gas vent passes through a roof constructed of combustible material it shall be guarded at the point of passage by a method described in 5.5.14 or by a noncombustible nonventilating thimble not less than 4-in. larger in diameter than the vent pipe and extending not less than 18-in. above and 6-in. below the roof with the annular space open at the bottom and closed only at the top.

c. In those sections of the country where solid and liquid fuels are used extensively, gas vent systems shall be plainly and permanently identified by a label reading:

"This gas vent is for appliances which burn gas only. Do not connect to incinerators or solid or liquid fuel burning appliances."

This label shall be attached to the wall or ceiling at a point near where the gas vent system enters the wall, ceiling or chimney.

The authority having jurisdiction shall determine whether the locality constitutes such an area.

5.3.3. Chimneys:

a. Listed factory-built chimneys shall be installed in accordance with their listings and the manufacturer's instructions.

b. Masonry or metal chimneys shall be built and installed in accordance with nationally recognized building codes.*

c. Before connecting a vent connector to a chimney, the chimney passageway shall be examined to ascertain that it is properly constructed, clear and free of obstruction or debris.

d. An automatically controlled gas appliance connected to a chimney which also serves equipment for the combustion of solid or liquid fuel shall be equipped with an automatic pilot. A gas appliance vent connector and a flue connector from an appliance burning another fuel may be connected into the same chimney through separate openings, or may be connected through a single opening if joined by a suitable fitting located as close as practical to the chimney. If two or more openings are provided into one chimney they should be at different levels.

e. Cleanouts shall be of such construction that they will remain tightly closed when not in use. Tee fittings used as cleanouts or condensate drains shall have tight fitting caps to prevent entrance of air into the chimney at that point.

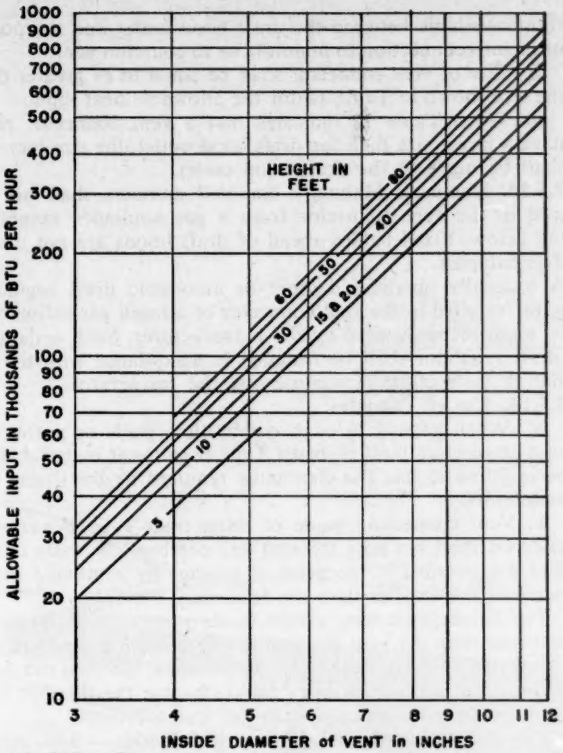


Fig. 13. Sizing Chart gives capacity in Btu per hour for gas vents or chimneys serving more than one appliance.

f. When an existing masonry chimney is unlined and where local experience indicates that vent gas condensate will be a problem, an approved liner or another vent shall be installed. When inspection reveals that an existing chimney is not safe for the intended application, it shall be rebuilt to conform to nationally recognized standards or relined with a suitable liner, or replaced with a gas vent or chimney suitable for the appliances to be attached.

5.3.4. Size of Gas Vent or Chimney: The gas vent or chimney when connected to a single appliance shall be not less than the size of the draft hood outlet, or as provided in 5.7.

When more than one appliance is connected to a gas vent or chimney, the area of the passageway shall be not less than the area of the largest vent connector plus 50 percent of the areas of additional vent connectors, or as provided in Fig. 13, or as provided in 5.7.

Any shaped gas vent may be used provided its venting capacity is equal to the capacity of round pipe for which it is substituted and the minimum internal dimension of the gas vent is not less than 2-in.

5.3.5. Gas Vent or Chimney Termination:

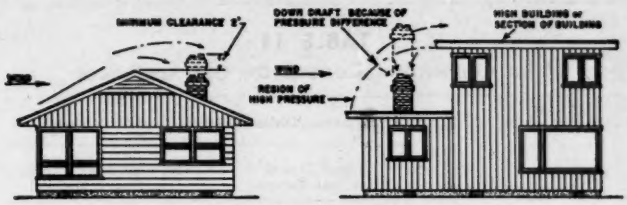
a. The gas vent or chimney should extend high enough above the building or other neighboring obstruction so that wind from any direction will not create a positive pressure in the vicinity of the gas vent or chimney termination.

b. Gas vents shall extend at least 2 ft above the highest point where they pass through a roof of a building and at least 2 ft higher than any portion of a building within 10 ft except that gas vents need not comply with this provision when equipped with an approved device and proper and effective venting is accomplished. Chimneys shall extend at least 3 ft above the highest point where they pass through the roof of a building and at least 2 ft higher than any portion of the building within 10 ft.

c. Gas vents or chimneys shall not terminate less than 4 ft in vertical height above the highest connected appliance draft hood outlet or flue collar except as provided in 5.6.1.

d. Type B-W gas vents serving a vented recessed heater shall not terminate less than 12 ft in vertical height above the bottom of the heater.

e. Gas vents and factory-built chimneys shall extend above the roof surface and through the flashing and shall terminate in a top or listed roof assembly with a venting capacity not less than that of the gas vent or chimney. The top shall be of a design to prevent rain and debris from entering the gas vent or chimney.


MINIMUM CLEARANCE 2'
DOWN DRAFT BECAUSE OF PRESSURE DIFFERENCE
HIGH BUILDING or SECTION OF BUILDING
WIND
REGION OF HIGH PRESSURE

Correct Chimney Designs Shown by Dotted Lines

Carry Chimney Well Above Roof of High Building

Fig. 14. Typical chimney conditions apt to result in back drafts.

5.3.6. Support of Gas Vents and Chimneys: All portions of gas vents and chimneys shall be adequately supported for the weight and design of the materials employed. Listed gas vents and factory-built chimneys shall be supported and spaced in accordance with their listings and the manufacturer's instructions.

5.3.7. Gas Vent or Chimney Serving Two or More Gas Appliances Having Draft Hoods: When two or more vent connectors enter a common vertical gas vent or chimney, the smaller connector should enter at the highest level consistent with available headroom or clearance to combustible material.

Two or more gas appliances may be vented through a common vent connector or manifold located at the highest level consistent with available (normal) headroom or clearance to combustible material (see 5.5.12).

The manifold, all junction fittings, and the common vent connector shall be of a size adequate for the combined volume of the vent gases (see 5.5.12).

5.4. Outside Gas Vents and Chimneys

5.4.1. Materials: Outside gas vents and chimneys are not recommended for use in cold climates. When they must be used in these climates, the material shall possess high insulation qualities or be adequately insulated.

5.4.2. Condensate Drain: When local experience with a gas vent material indicates that condensate may be a problem, a capped tee and drain pipe shall be installed at the base of the riser to drain off condensate when such material is used.

5.4.3. Prohibited Termination: Natural draft vents extending through outside walls and terminating adjacent to outside walls or below eaves or parapets are prohibited.

5.5. Vent Connectors

5.5.1. Materials:

a. Vent connectors used for conversion burners without draft hoods, incinerators and unlisted appliances without draft hoods shall be constructed of materials having resistance to corrosion and heat not less than that of No. 24 U. S. gage galvanized steel.

b. Vent connectors used for gas appliances having draft hoods and for listed conversion burners having draft hoods shall be constructed of materials having resistance to corrosion and heat not less than that of No. 28 U. S. gage galvanized steel, except that Type B vent material may be used as the connector between the draft hood and the chimney.

5.5.2. Size: Vent connectors shall not be smaller than the size of the flue collar or the draft hood outlet, or as provided in 5.7. When the appliance has more than one draft hood outlet, and in the absence of the appliance manufacturer's specific instructions, the vent connector shall equal the combined area of the draft hood outlets for which it acts as a common connector to the gas vent or chimney.

5.5.3. Clearance: Minimum clearances of vent connectors to combustible material shall be in accordance with Table 11.

The clearances from vent connectors to combustible materials may be reduced when the combustible material is protected as specified in Table 10.

When vent connectors must pass through walls or partitions of combustible material, a thimble shall be used, which shall be installed in accordance with one of the methods outlined in 5.5.14.

5.5.4. Avoid Unnecessary Bends: The vent connector shall be installed so as to avoid excessive turns or other construction features which create unnecessary resistance to flow of vent gases.

5.5.5. Joints: Vent connectors shall be firmly attached to draft hood outlets by sheet metal screws or other approved means.

TABLE 11

Vent Connector Clearances for Gas Appliances.

Appliance	Minimum Distance from Combustible Material	
	Listed Type B Gas Vent Material	Vent Connectors of Other than Type B Material
Listed Boiler	As Listed	6 inches
Listed Warm Air Furnace	As Listed	6 inches
Listed Water Heater	As Listed	6 inches
Listed Room Heater	As Listed	6 inches
Listed Floor Furnace	As Listed	6 inches
Listed Incinerator	Not Permitted	18 inches
Listed Conversion Burner (with draft hood)	6 inches	9 inches
Unlisted Appliances having draft hoods	6 inches	9 inches
Unlisted Appliances without draft hoods	Not Permitted	18 inches

TABLE 12

Allowable Input to Vent Connectors Before Interconnection

Connector Sizes in Inches	Maximum Appliance Input—in Btu per Hour
3	30,000
4	55,000
5	80,000
6	125,000
7	180,000
8	245,000
9 and above	5,000 Btu per sq in. of cross-sectional area

Vent connectors using listed Type B gas vent material shall be securely assembled using the method shown in the listing and the manufacturer's instructions.

Joints of other than listed Type B gas vent material shall be securely fastened by sheet metal screws or other approved methods.

5.5.6. Pitch: Vent connectors attached directly to side outlet draft hoods, such as on floor furnaces, shall be pitched upward from the appliance at least ¼-in. per ft.

Vent connectors attached to top outlet draft hoods by means of a 90-deg elbow may be horizontal or pitched upward from the appliance.

No portion of any vent connector shall be run downward from the appliance nor shall there be any dips or sags.

5.5.7. Length: The horizontal run of the vent connector shall be as short as possible and the appliance shall be located as near the gas vent or chimney as practicable. The maximum length of an uninsulated horizontal run of vent connector shall not exceed 75 percent of the height of the gas vent or chimney.

5.5.8. Support: Vent connectors shall be securely supported for the weight and design of the materials employed to maintain proper clearances, to prevent physical damage, and to prevent separation of the joints.

5.5.9. Location: When the vent connector used for an appliance having a draft hood must be located in or pass through a crawl space or other area difficult of access which may be cold, that portion of the vent connector shall be of listed Type B gas vent material or material having equivalent insulation qualities. Type C gas vent material used as a vent connector shall not pass through any floor or ceiling.

5.5.10. Chimney Connection: In entering a passageway in a masonry or metal chimney the vent connector shall be installed above the extreme bottom to avoid stoppage. Means shall be employed which will prevent the vent connector from entering so far as to restrict the space between its end and the opposite wall of the chimney. A thimble or slip joint may be used to facilitate removal of the vent connector. The vent connector shall be firmly attached or inserted into the thimble or slip joint to prevent it from falling out.

5.5.11. Fireplace: A vent connector shall not be connected to a chimney serving a fireplace unless the fireplace opening is permanently sealed.

5.5.12. Size, Height and Length of Interconnected Vent Connectors: Two or more vent connectors may be joined through a gas vent manifold, or directly to a chimney or to a gas vent provided that:

a. Vent connectors carrying the gases of a single appliance shall have the greatest possible rise consistent with the headroom available between the draft hood outlet and the points of its interconnection to manifold or to common vent.

b. Size of vent connector shall be equal to or greater than the size shown in Table 12 for the allowable heat input.

c. When Table 12 indicates that a vent connector must have a larger size than the draft hood outlet, the size increase shall be made at the draft hood outlet.

5.5.13. Dampers: Manually operated dampers shall not be placed in the vent connector from a gas appliance except as noted below. Fixed baffles ahead of draft hoods are not classified as dampers.

A manually operated damper or automatic draft regulator may be installed in the vent connector of a listed gas incinerator only when recommended by the manufacturer. Such a damper or draft regulator shall be installed in accordance with the installation instructions accompanying the incinerator.

5.5.14. Use of Thimbles:

a. When passing through combustible walls or partitions, vent connectors built of listed Type B gas vent material shall be installed so that the clearances required by the listing are maintained

b. Vent connectors made of other than Type B gas vent material shall not pass through any combustible walls unless they are guarded at the point of passage by ventilated metal thimbles not smaller than the following:

For listed appliances, except incinerators — 4-in. larger in diameter than the vent connector, unless there is a run of not less than 6 ft of vent connector in the open, between the draft hood outlet and the thimble, in which case the thimble may be 2-in. larger in diameter than the vent connector.

For unlisted appliances having draft hoods — 6-in. larger in diameter than the vent connector.

For incinerators and unlisted appliances without draft hoods — 12-in. larger in diameter than the vent connector.

c. In lieu of thimble protection, all combustible material in the wall shall be cut away from the vent connector a sufficient distance to provide the clearance required from such vent connector to combustible material. Any material used to close up such opening shall be noncombustible.

5.6. Special Venting Arrangements

5.6.1. Appliances with Sealed Combustion Chambers: The provisions of draft hoods as shown in Part III and Sections 5.2.2 through 5.5 inclusive, do not apply to listed appliances having sealed combustion chambers and which are so constructed and installed that all air for combustion is derived from outside the space being heated and all flue gases are discharged to the outside atmosphere. Such appliances, having integral venting, shall be considered as being properly vented when they are installed in accordance with their listing and the manufacturer's instructions.

5.6.2. Gas Vent and Chimney Exhausters:

a. Gas vent and chimney exhausters may be used with gas appliances in lieu of natural draft vents, except for incinerators. When an exhauster is used with gas appliances requiring venting, provisions shall be made to prevent the flow of gas to the main burner in the event of failure of the exhaust system.

b. A vent connector serving a gas appliance vented by natural draft shall not be connected into the discharge side of a power exhauster.

5.6.3. Ventilating Hoods and Exhaust Systems:*

a. Ventilating hoods and exhaust systems may be used to vent gas burning appliances installed in commercial applications.

b. When automatically operated appliances, such as water heaters, are vented through natural draft ventilating hoods, dampers shall not be installed in the ventilating system. When the ventilating hood or exhaust system is equipped with power means of exhaust, the appliance control system shall be so interlocked as to permit appliance operation only when the power means of exhaust is in operation.

5.7. Engineered Vent Systems

The size of chimneys, gas vents or vent connectors specified in Part V shall not necessarily govern where standard engineering methods have been used to design the vent system.

*Information on the construction and installation of ventilating hoods may be obtained from NFPA No. 96, Standard on Ventilation of Restaurant Cooking Equipment, available from the National Fire Protection Association, 60 Batterymarch Street, Boston 10, Massachusetts.

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1. Gives ⅓rd more power without pistons or valves.
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AVERAGE ECONOMY OF INDUSTRIAL FURNACES WITH GOOD OPERATION

Process	Millions of Btu per net ton	Efficiency per cent
FERROUS PRODUCTS		
ngot heating, soaking pits	1.0	24
illet heating for forming batch—		
In-and-out type	3.5	20
Continuous non-recuperative	2.2	32
Bar annealing, pit or car type	2.6	17
Wire annealing—hood type, coils	2.7	16
strand in lead	2.2	19
strand, open fired	1.2	32
stainless, catenary strand	2.7	24
Caustic pickle, stainless wire coils	0.7	26
Wire temper, open heat, lead quench	4.0	19
Wire patenting, strands	2.5	20
Wire galvanizing, strands	0.8	30
Wire tinning, strands	0.4	35
Wire baking, coils, continuous	0.5	32
Nail galvanizing, retort	0.3	—
Nail blueing, continuous retort	0.4	—
Tube reheating, sizing mill	1.5	18
Tube annealing—Continuous, bright	1.2	35
batch, car type	1.5	28
Tube normalizing. continuous roll-down	1.7	33
Tube galvanizing	1.2	20
Skelp heating, butt weld—batch	3.8	20
continuous	3.0	25
Slab heating, continuous recuperative	1.6	43
Sheet bar heating—batch	2.2	22
continuous	1.7	29
Sheet and strip annealing, hood type—		
Carbon steels	1.2	27
Alloy steels	2.0	19
Strip annealing, continuous coils	1.6	24
Strip, bright annealing, strands	1.2	32
Sheet normalizing, continuous, wasters	3.5	17
Sheet galvanizing	1.0	24
Nickle stainless sheet anneal, strands	3.0	21
Caustic pickle stainless strip, continuous	0.3	—
Nickle stainless sheet anneal, batch	4.5	16
Enamelling — cast iron, three coats, batch	4.0	21
Flat ware, continuous	2.6	18
Hardening, continous conveyor type	2.5	20
Drawing, continous conveyor type	1.5	21
Carburizing, boxes, continuous	4.5	12
Carburizing, gas, continuous	3.0	18
Annealing steel castings	3.7	13
NON-FERROUS PRODUCTS		
Copper and brass—		
Billet or cake heating, continuous	0.8	30
Wire annealing — coils, continuous	1.5	16
strands, bright	1.1	22
Sheet and strip anneal, continuous, pans	0.8	30
Cartridge case anneal, continuous	1.3	19
Aluminum —		
Billet heating	1.4	32

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FUEL CONSUMPTION OF TYPICAL FURNACES

Brick, kilns:	Btu/1000 Brick
Hoffman continuous kiln	3,920,000-4,760,000
Ruebon kiln	5,880,000-9,240,000
Grates and trough	4,760,000-6,300,000
Staffordshire kiln	4,760,000-6,300,000
Buhrer continuous tunnel	3,220,000-3,900,000
Metal melting:	Btu/Ton
Iron and steel:	
Puddling	14,000,000
Open-hearth	3,000,000-6,500,000
Air furnace for malleable castings	8,600,000
Copper, reverberatory	4,200,000
Tin, smelting	19,200,000
Rolling-mill furnaces:	
Busheling	5,600,000-7,000,000
Billet heating	2,240,000-2,520,000
Billet heating (4 by 4)	2,800,000-4,200,000
Continuous furnace (cold billets)	1,500,000-2,250,000
Continuous-bloom furnace	1,400,000-2,100,000
Reheating cold blooms	1,960,000-2,800,000
Soaking pits (hoit to cold ingots)	250,000-2,000,000
Tire furnaces	4,500,000
Wheel furnaces	8,400,000
Sheet annealing	2,800,000
Tin-plate mill	2,500,000
Rivet making:	
Rivet-making furnaces	1,260,000
Forging:	
Drop forging or bolt heating	6,000,000-7,000,000
Ingot forging	4,000,000-5,000,000
Ingot forging (regeneration furnace)	3,500,000-4,000,000
Brass annealing	1,500,000-2,000,000
Heat-treatment:	
Casehardening	4,500,000-5,000,000
Quenching	2,000,000-3,000,000
Tempering	1,500,000-2,000,000

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INDUSTRIAL HEATING OPERATIONS

Materials, operations and approximate temperature range

Material	Operation	Approx. Temp. Range (°F)
Aluminum alloy	Aging	250–460
Aluminum alloy	Annealing	450–775
Aluminum alloy	Forging	750–900
Aluminum alloy	Heat treating	310–1000
Aluminum	Melting	1200–1400
Aluminum alloy	Die casting	1250–1400
Antimony	Melting polint	1166
Asphalt	Melting	350–450
Babbitt	Melting	600–800
Brass	Annealing	600-900
Brass	Extruding	1400–1450
Brass	Forging	1200–1400
Brass, yellow	Melting	1705
Brass, red	Melting	1830
Bread	Baking	300–500
Brick	Burning	1800–2600
Brick, refractory	Burning	2500–3000
Bronze, 5% alum.	Melting	1940
Bronze, man.	Melting	1645
Bronze, phos.	Melting	1920
Bronze, tobin	Melting	1625
Cadmium	Melting point	610
Cake (food)	Baking	300–350
Calcium	Melting point	1562
Calender rolls	Heating	300
Candy	Cooking	225–300
Cast iron	Annealing	1600–1700
Cast iron	Malleablizing	1650–1800
Cast iron	Vitreous enameling	1200–1300
Cement	Kiln firing	2800–3000
China	Glazing	1500–1900
Clay, refrac.	Burning	2200–2600
Cobalt	Melting point	2714
Coffee	Roasting	600–800
Coke	By-product oven	1830–2730
Cookies	Baking	375–450
Copper	Annealing	800–1200
Copper	Refining	2100–2600
Copper	Melting	2100–2300
Copper	Smelting	2100–2600
Cores, sand	Baking	250–550
Cupronickel, 15%	Melting	2150
Cupronickel, 30%	Melting	2240
Electrotype	Melting	740
Enamel	Baking	250–450
Everdur 1010	Melting	1865
Frit	Smelting	2000–2400
Glass	Annealing	800–1200
Glass	Melting, pot furnace	2300–2500
Glass, bottle	Melting, tank furnace	2500–2900
Glass, flat	Melting, tank furnace	2500-3000
Gold	Melting	1950–2150
Iron	Blast furnace tap.	2500–2800
Iron, malleable	Melting	2400–3100
Iron, malleable	Annealing	1500–1700
Japan	Baking	300– 450
Lacquer	Drying	150–200
Lead	Melting	620–750
Lead	Blast furnace	1650–2200
Lead	Refining	1800–2000
Magnesium	Aging	350–400
Magnesium	Heat treating	730–760
Magnesium	Melting	1250–1300
Magnesium	Superheating	1450–1650
Meat	Smoking	100–150
Mercury	Melting point	–38
Molds, foundry	Drying	400–750
Molybdenum	Melting point	4757
Monel metal	Annealing	1100–1480
Monel metal	Melting	2800
Muntz metal	Melting	1660
Nickel	Annealing	1100–1480
Nickel	Melting	2650
Palladium	Melting point	2829
Phosphorous, yellow	Melting point	111
Pie	Baking	500
Pigment	Calcining	1600
Platinum	Melting	3224
Porcelain	Burning	2600
Potassium	Melting point	145
Potato chips	Frying	350–400
Primer	Baking	300–400
Silicon	Melting point	2606
Silver	Melting	1750–1900
Sodium	Melting point	208
Solder	Melting	400–600
STEEL		
Steel, Sheet	Blue annealing	1400–1600
Sheet	Box annealing	1500–1700
Sheet	Bright annealing	1250–1350
Sheet	Job mill heating	2000–2100
Sheet	Mill heating	1800–2100
Sheet	Open annealing	1500–1700
Sheet	Tin plating	650
Sheet	Vitreous enameling	1400–1650
Sheet, tin plate	Box annealing	1200–1650
Sheet, tin plate	Hot mill heating	1800–2000
Sheet, tin plate	Lithographing	300
Steel	Bessemer converter	2800–3000
Steel	Calorizing	1700
Steel	Carburizing	1500–1700
Steel	Case hardening	1600–1700
Steel	Cyaniding	1400–1800
Steel	Drawing forgings	850
Steel	Drop forging	2200–2400
Steel	Forging	1700–2150
Steel	Form-bending	1600–1800
Steel	Galvanizing	800–900
Steel	Heat treating	700–1800
Steel	Lead hardening	1400–1800
Steel	Melting, open hearth	2800–3100
Steel	Melting, electric furn.	2400–3200
Steel	Normalizing	1650–1900
Steel	Rolling	2300
Steel	Soaking pits	1900–2100
Steel	Upsetting	2000–2300
Steel	Welding	2400–2800
Steel bars	Heating	1900–2200
Steel billets	Heating	2250
Steel blooms	Heating	2250
Steel bolts	Heading	2200–2300
Steel castings	Annealing	1300–1600
Steel flanging	Heating	1800–2100
Steel ingots	Heating	2000–2200
Steel nails	Blueing	650
Steel pipe	Butt welding	2400–2600
Steel rails	Hot bloom reheating	1900–2050
Steel rivets	Heating	2000–2200
Steel rod	Mill heating	1900–2100
Steel shape	Heating	1900–2200
Steel slabs	Heating	2000–2200
Steel spikes	Heating	2000–2200
Steel springs	Annealing	1500–1650
Steel wire	Annealing	1200–1400
Steel wire	Pot annealing	1650
Steel wire	Baking	300–350
Steel, alloy tool	Hardening	1425–2150
Steel, alloy tool	Preheating	1200–1500
Steel, alloy tool	Tempering	325–1250
Steel, carbon	Hardening	1360–1550
Steel, carbon tool	Hardening	1450–1500
Steel, carbon	Tempering	300–1100
Steel, carbon tool	Tempering	300–550
Steel, hi-carbon	Annealing	1400–1500
Steel, hi-speed	Hardening	2250–2375
Steel, hi-speed	Preheating	1450–1600
Steel, hi-speed	Tempering	1000–1150
Steel, S.A.E.	Annealing	1400–1650
Tin	Melting	500–650
Type metal	Stereotyping	525–650
Type metal	Linotyping	550–650
Type metal	Electrotyping	650–750
Varnish	Cooking	520–600
Vitreous enamel	Firing	1400–1700
Zinc	Melting	800–900
Zinc alloy	Die casting	850

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Conversion Factor Data

Length

	Centimeter =	Foot =	Inch =	Kilometer =	Meter =	Mile =
Centimeters	1	30.48006	2.54	100,000	100	160,934.7
Feet	0.0328	1	0.08333	3281	3.280833	5280
Inches	0.3937	12	1	39,370	39.37	63,360
Kilometers	0.00001	0.0003048	0.0000254	1	0.001	1.6093
Meters	0.01	0.3048006	0.0254	1000	1	1,609.3
Miles	0.00000621	0.0001893	0.00001578	0.6214	0.000621	1
Millimeters	10	304.8	25.4	1,000,000	1000	1,609,347.2

Area

	Sq Centimeter =	Sq Foot =	Sq Inch =	Sq Meter =
Sq Centimeters	1	929	6.45	10,000
Sq Feet	0.001076	1	0.006944	10.76
Sq Inches	0.1550	144	1	1549.9
Sq Meters	0.0001	0.0929	0.000645	1
Sq Millimeters	100	92,900	645.2	1,000,000

Volume

	Cu Centimeter =	Cu Foot =	Cu Inch =	Cu Meter =	Gal. (U.S.) =	Liters =	Barrels =
Cu Centimeters	1	28,317.016	16.39	1,000,000	3785	1000	158,970
Cu Feet	0.00003531	1	.0005787	35.31	0.133680	0.03531	5.614
Cu Inches	0.06102	1728	1	61,023	231	61.02	9702
Cu Meters	0.000001	0.028317	0.00001639	1	0.003785	0.001	.1589
Gal. (U.S.)	0.0002642	7.481	0.004329	264.2	1	0.2642	42

Mass & Weight

	Kilogram =	Pound =	Ton (long) =	Ton (Metric) =	Ton (short) =	Ounce =
Grams	1000	453.6	1,016,047	1,000,000	907,200	28.35
Kilograms	1	0.4536	1016	1000	907.2	0.02835
Milligrams	1,000,000	453,600	1,016,047,040	1,000,000,000	907,200,000	28,350
Pounds	2.205	1	2240	2204.6	2000	0.0625
Ounces	35.274	16	35,840	35,274	32,000	1

Density

	Grams/cc =	Kg/cu meter =	lb/cu ft =	lb/cu in. =
Grams/cu cent.	1	0.001	0.01602	27.68
kilograms/cu meter	1000	1	16.02	27,680
lb/cu ft	62.43	0.06243	1	1728
lb/cu in.	0.03613	0.00003613	0.0005787	1

Pressure

	Atmosphere =	In. of Mercury at 0 C =	In. of Water at 4 C =	Ft of Water at 4 C =	Kilograms/Sq Meter =	Lb/Sq In. =
Atmospheres	1	0.03342	0.002458	0.02950	0.00009678	0.06804
In. of Mercury at 0 C	29.92	1	0.07355	0.8826	0.002896	2.036
In. of Water at 4 C	406.8	13.60	1	12	0.03937	27.68
Ft of Water at 4 C	33.90	1.133	0.08333	1	0.003281	2.307
Lb/Sq In.	14.70	0.4912	0.03613	0.4335	0.001422	1

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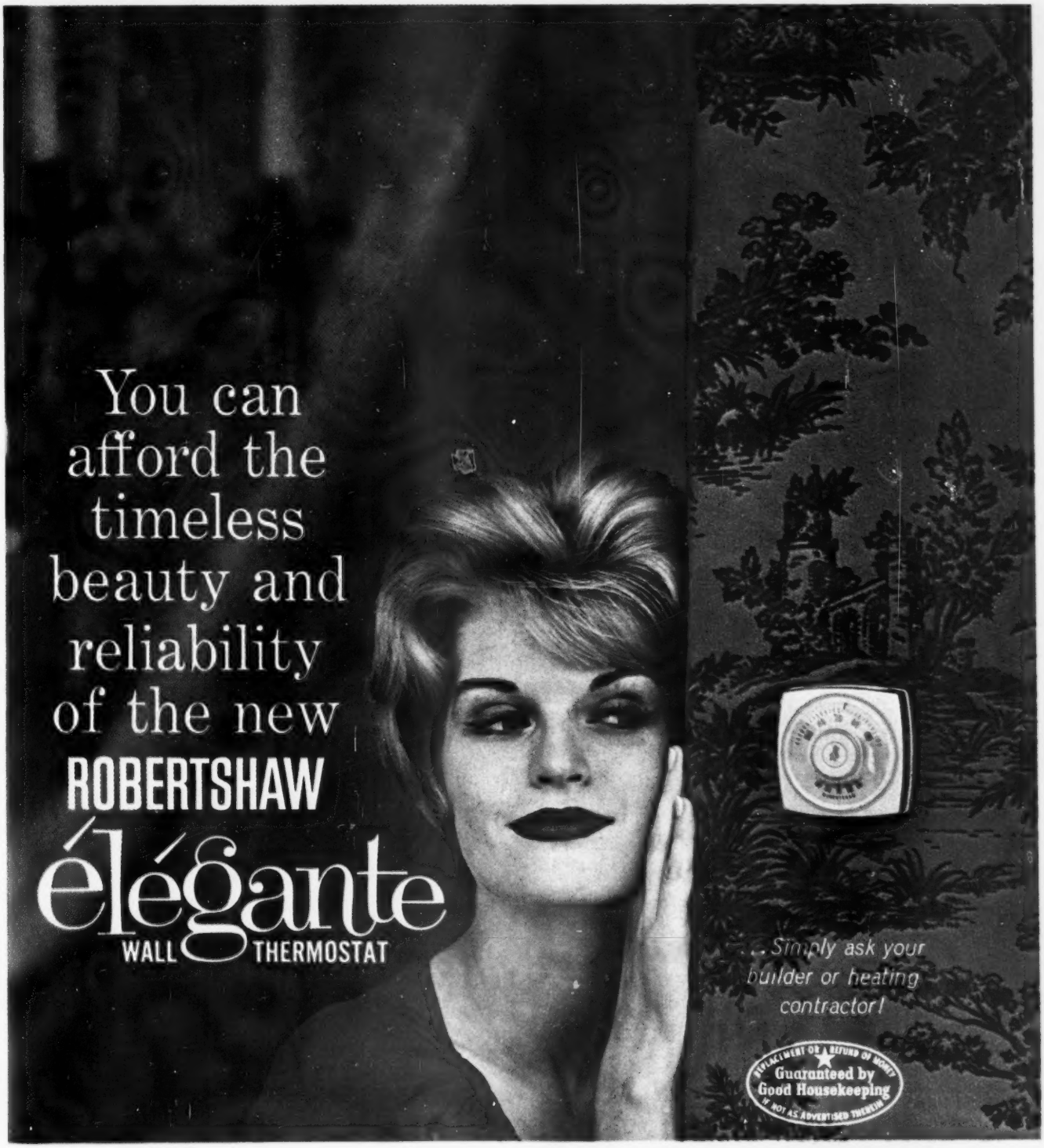
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provides trouble-free operation,
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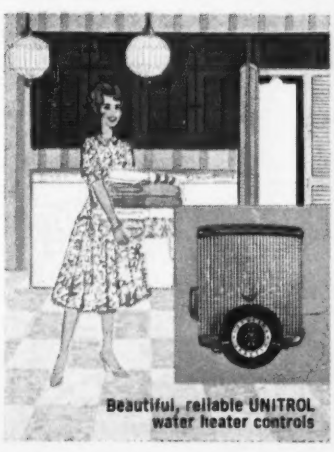
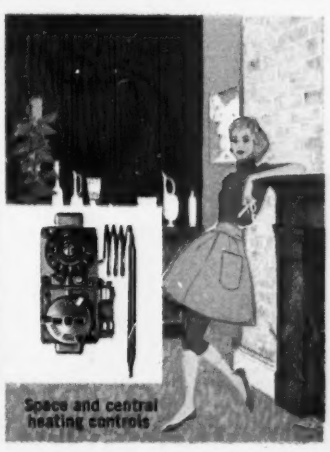
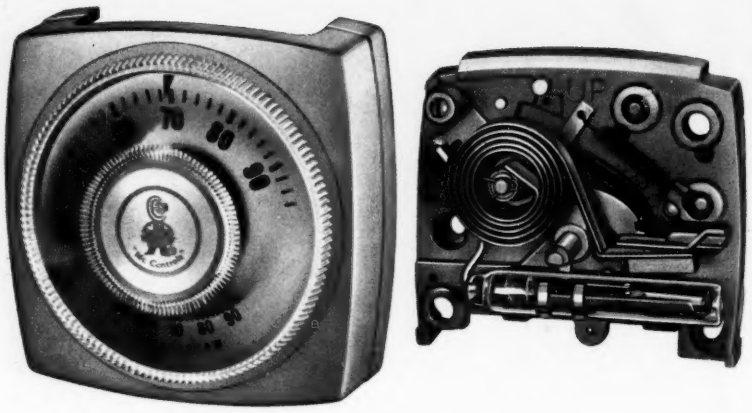


Beautiful, reliable UNITROL water heater controls

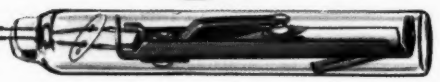


Space and central heating controls

Why there is a one best switch in central heating...



ROBERTSHAW'S new élégante



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Operates in any position— needs no leveling.

HERE'S HOW IT WORKS:

The new Robertshaw élégante wall thermostat features an exciting new concept in low voltage switches. Sealed in glass, this patented switch (above) is actuated by a magnet brought into proximity of the contacts. Simplicity and a minimum of moving parts—plus the sealed in glass principle (protects from dust and moisture)—make the new Robertshaw élégante the most reliable wall thermostat ever developed!

The new Robertshaw élégante wall thermostat features classic architectural design and timeless beauty which will be in style for many, many years to come.

This new switch principle guarantees long life and trouble free operation. In addition, Robertshaw's years of engineering experience in the controls industry assures consumer satisfaction.

When you specify the exciting new Robertshaw élégante, you can be sure that you are giving your customer the finest, most **tested** wall thermostat ever produced.

NEWEST, BEST
SMARTEST
MOST RELIABLE
EASIEST TO INSTALL
MOST BEAUTIFUL
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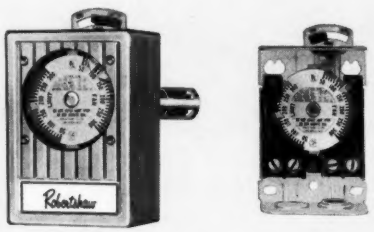


All new full load fan and limit switch offers you more new features!

Ask about the new Robertshaw full load Fan and Limit Switch (¾ hp—14 amp.)... incorporates many new engineering ideas—saves you inventory and installation costs!

Robertshaw

GRAYSON CONTROLS DIVISION
Long Beach 5, California

Conversion Factor Data

Linear Velocity

	Centimeter/sec =	Foot/min =	Foot/sec =	Mile/hr =
Centimeters/sec	1	0.5080	30.48	44.70
Feet/min	1.969	1	60	88
Feet/sec	0.03281	0.01667	1	1467
Miles/hr	0.02237	0.01136	0.6818	1

Heat, Work, or Energy

	Ft-lb =	Kw-hr =	Hp-hr =	Btu =	Calories =
Ft-lb	1	2,655,000	1,980,000	778.16	3.086
Kw-hr	0.3766×10^{-6}	1	0.7455	0.000293	0.1162×10^{-5}
Hp-hr	0.505×10^{-6}	1.341	1	0.000393	0.1558×10^{-5}
Btu	0.001285	3413	2545	1	0.00397
Calories	0.3241	860,565	641,615	252	1

Miscellaneous Conversions

Land Measure

1 rod = 16.5 feet = 5.5 yards
1 mile = 5280 feet = 1760 yards = 320 rods
1 furlong = 10 chains = 40 rods = 660 feet
1 square mile = 1 section = 640 acres = 102,400 square rods
1 acre = 43,560 square feet = $(208.71 \text{ ft})^2$

Nautical Measure

6080.27 feet = 1 nautical mile = 1.15156 statute miles
3 nautical miles = 1 league (U. S.)

Circular Inch

1 circular inch = 0.7854 square inch
= (area of circle 1 inch in diameter)
1 square inch = 1.2732 circular inches

Metric Multiples (Volume)

1 centiliter	= 10 milliliters	= 0.338 fluid ounce
1 deciliter	= 10 centiliters	= 0.845 liquid gill
1 liter	= 10 deciliters	= 1.0567 liquid quarts
1 dekaliter	= 10 liters	= 2.6417 liquid gallons
1 hectoliter	= 10 dekaliters	= 2.8375 U. S. bushels
1 kiloliter (or stere)	= 10 hectoliters	= 28.375 U. S. bushels

Liquid Measure

1 U. S. gallon (liquid) = 0.8327 Imperial gallon
1 Imperial gallon = 1.201 U. S. gallons (liquid)
1 U. S. gallon (liquid) = 0.8594 U. S. gallon (dry)
1 cubic foot = 7.4805 gallons (liquid)
1 U. S. gallon (liquid) = 231 cubic inches
1 U. S. gallon (liquid) = 8.336 lb water @ 62 F

Time

1 day = 24 hours
= 1440 minutes
= 86,400 seconds
1 hour = 0.04167 day
= 60 minutes
= 3600 seconds
1 week = 7 days
= 168 hours
= 10,080 minutes
= 604,800 seconds

Rate of Doing Work

1 Btu = 778 ft-lb per minute
= 12.97 ft-lb per second
= 0.02357 horsepower
= 17.58 watts
1 horsepower = 42.41 Btu per minute
= 33,000 ft-lb per minute
= 550 ft-lb per second
= 745.7 watts
1 kilowatt = 3413 Btu per hour
= 1.341 horsepower
1 boiler horsepower = 33,479 Btu per hour
= 9.804 kilowatts

Temperature Conversions

Absolute Temperature, deg. C = Deg. Centigrade + 273
Temperature in deg. F = (Deg. Centigrade + 17.8) × 1.8
Absolute temperature, deg. F = Deg. Fahrenheit + 460
Temperature in deg. C = (Deg. Fahrenheit — 32) × 5/9

AGA Recommended Good Practice Requirements For

Installation of Gas Piping and Equipment On Industrial and Commercial Premises

(Not applicable to undiluted liquefied petroleum gas.)

Relates to piping systems and equipment not covered by ASA Z21.30-1959 (Installation of Gas Appliances and Piping) and ASA Z21.33-1950 (Installation of Gas Equipment in Large Boilers).

EDITOR'S NOTE: This section has been developed by combining Information Letters 70 and 70-A, issued by the AGA Industrial Gas Practices Committee, which are ultimately intended to serve as parts of a proposed American Standard. Therefore the words *standards, approved, shall* and *should* follow usage consistent with the ultimate objective. Inasmuch as this material has been issued as an information letter, it does not, as yet, have a status of a standard.

Under this caption appear the fundamental standards that should be observed during the installation of gas piping and equipment and recommendation for the selection of suitable gas equipment to insure safety and consumer satisfaction. Responsibility for observing these standards shall rest with the person or agency making and/or authorizing the installation.

PART I – GENERAL

1.1 Scope

These basic standards supplement the American Standard Code for Pressure Piping (ASA B 31.1-1955)* and the American Standard for Gas Transmission and Distribution Piping Systems (ASA B31.1.8-1958).* These standards which follow govern the installation of consumer-owned gas piping, both in buildings and between buildings extending from the outlet of the gas meter set assembly, or point of delivery, to the inlet connections on gas utilization equipment. These standards are intended to cover piping systems for industrial installations at any pressure and for all other non-residential installations at operating pressures in excess of ½ psig. They cover the installation and testing of these systems for fuel gases such as natural gas, manufactured gas, liquefied petroleum gas-air, or mixtures of these gases. They do not cover systems for undiluted liquefied petroleum gas.

NOTE: In applying these standards, reference should also be made to equipment manufacturer's instructions, gas company regulations, and local building, plumbing, gas and steam-fitting codes, or other applicable codes in effect in the area in which the installation is made.

The word *approved* as used in these standards means acceptable to the authority having jurisdiction.

Shall is intended to indicate requirements.

Should is intended to indicate recommendations, or that which is advised but not required.

1.2 Precautions Covering Work on Gas Company Facilities Including Mains, Services and Equipment up to and Including the Gas Meter Set Assembly

Paragraphs 1.2.1 to 1.2.5 inclusive are not a part of these standards but are included for information only.

1.2.1 Gas Company's Main. No person, unless in the employ of the Gas Company, or having permission from the Gas Company, shall open or make connections to a Gas Company main.

1.2.2 Service Pipe. No person, unless in the employ of the Gas Company or having permission from the Gas Company, shall repair, alter, open or make connection to the service pipe, or do any other work on the parts of the gas supply system up to and including the meter set assembly except as covered under 1.2.5.

1.2.3 Gas Company's Meter Set Assembly. No person, unless in the employ of the Gas Company or having permission from the Gas Company, shall disconnect or move the gas meter set assembly. If it becomes necessary to turn off the meter for any reasons, gas shall be turned on again only in accordance with Sections 2.11 and 2.12.

1.2.4 Notify Gas Company of Any Repairs Needed. If a need for repairs or alterations on any part of the gas supply system is disclosed, the Gas Company shall be notified promptly of this fact.

1.2.5 Notify Gas Company of Any Leaks. If gas is leaking from any part of the gas supply system, a gas fitter, steam fitter, or plumber not in the employ of the Gas Company may take necessary temporary repairs on the exposed piping only and shall promptly notify the Gas Company. Permanent repairs shall be made by the Gas Company.

1.3 General Safety Regulations

1.3.1 New Connections. Connections to gas piping systems should normally be made with gas shut off ahead of the point of work. However, hot taps may be made if they are installed by trained and experienced personnel, adequately equipped.

1.3.2 Notification of Interrupted Service. It shall be the duty of anyone shutting off the gas to notify all affected points of consumption.

1.3.3 Before Turning Gas Off. Except in the case of emergencies, before turning off the gas at the meter, all burner and pilot valves on the premises supplied with gas through the meter shall be turned off and the meter test hand observed for a sufficient length of time to ascertain that there is no gas passing through the meter. Where there is more than one meter on the premises, precautions shall be exercised to assure that the proper one is turned off. Before turning off the gas at any valve, all equipment supplied with gas through that valve shall be turned off.

Before turning gas back on, the provisions in Section 2.11 shall be followed.

1.3.4 Inspection for Gas Leaks. Inspection for leaks shall be made with approved leak detectors or by brushing a soap and water solution, or its equivalent, on the fittings and other suspected locations. No matches, candles, flame, or other sources of ignition shall be used during such inspections. See provisions of Sections 2.10.3 and 2.11.3.

When inspecting for gas leaks do not operate electric switches either on or off, due to possibility of sparks. This applies also to switches located outside of the area but connected by conduits to the affected space. Use flash lights, preferably of the safety type. If necessary clear building of occupants, ventilate, shut off gas and investigate other buildings in the area.

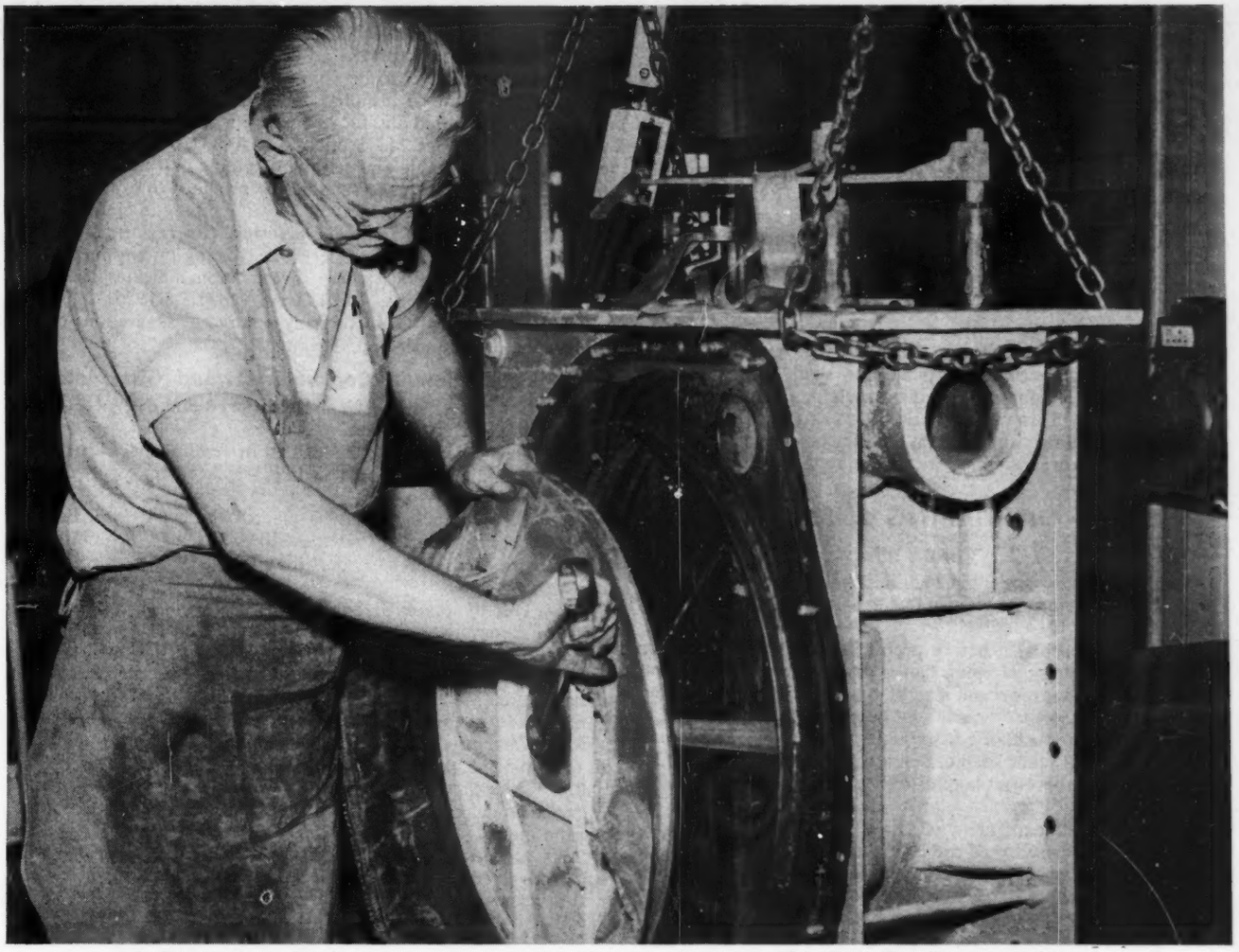
1.3.5 Working Alone. An individual shall not work alone in any situation where accepted working practice dictates that two or more men are necessary to perform the work safely.

1.3.6 Handling of Liquid from Drips. Liquid which is removed from a drip pot in existing gas piping shall be handled cautiously to avoid spillage or ignition and shall not be left on the premises. Call the local gas company for disposal recommendations.

1.3.7 No Smoking or Open Flames. When working on piping which contains or has contained gas, no smoking, open flames, lanterns, welding or other sources of ignition shall be permitted until proper safety precautions have been taken.

1.3.8 Handling Flammable Liquids. Flammable liquids used by the installer shall be handled with proper precautions and shall

*Available from American Society of Mechanical Engineers, 29 West 39th Street, New York 18, New York.



In large volume displacement meters—and in all types of meters—Ohio Fuel Gas Company relies on Reeves-Vulcan synthetic diaphragms for greater dependence, longer life and lower maintenance costs.

"We greatly reduced P.D. meter maintenance with Reeves-Vulcan synthetic diaphragms"

M. P. DeBaets, General Superintendent Gas-Measurement Department, Ohio Fuel Gas Company, Columbus, Ohio

"The frequent replacement of leather diaphragms required in large-volume, positive-displacement meters on gas wells," says Mr. DeBaets of Ohio Fuel Gas, "was, at one time, one of our major maintenance problems."

Problem: "When we were using leather diaphragms, the impurities in the wellhead gas would wash the oil out of the diaphragms, and diaphragms had to be replaced frequently. And cold weather aggravated the situation."

Solution: "About 6 years ago, we changed to Reeves-Vulcan synthetic diaphragms for these meters, as well as for industrial and domestic meters. Our experience shows that Reeves-Vulcan synthetic diaphragms last longer... withstand wellhead gas impurities...operate better at low temperatures... are not affected by odorants. What's more, since they require no oil, maintenance schedules have been extended."

Since changing to Reeves-Vulcan synthetic diaphragms, Ohio Fuel Gas reports substantial savings through reduction in meter maintenance and testings, and a much lower rate of diaphragm replacement. How about *your* metering efficiency?

There's a Reeves-Vulcan diaphragm for practically every type of gas meter made. Both molded and crimped styles are available in any volume. Order Reeves-Vulcan synthetic diaphragms from leading manufacturers or directly from:

REEVES VULCAN

Reeves Brothers, Inc., Vulcan Rubber Products Division
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not be left inside a building upon completion of a job or during non-working hours.

1.3.9 Work Interruptions. When interruptions in work occur, the system shall be left in a safe condition.

1.3.10 Back-Pressure Protection. When gas burning equipment is to be installed which employs air or other gases at higher than normal gas pressures, suitable provisions shall be made to protect against reverse flow in gas lines. The local gas company shall be consulted for details. Also see 846.32 in ASA B31.1.8-1955.

1.3.11 Low-Pressure Protection. When gas compressors or other equipment is used which might reduce supply pressures, suitable provisions shall be made to prevent dangerous pressure reductions on the inlet side of such devices. The local gas company shall be consulted for details. Also see 846.32 in ASA B31.1.8-1955.

1.3.12 Gas Piping as Electric Grounds. The gas piping shall not be used for an electric ground nor shall electric circuits utilize gas piping, casing of controls, panels or other metal parts in lieu of wiring. This provision shall not apply to low voltage control and ignition circuits, and to electronic flame detection device circuits incorporated as part of the appliance.

PART II – GAS PIPING INSTALLATION

2.1 Piping Plan

A suitably located space and facilities shall be provided for the Gas Company meter as agreed upon between the Gas Company and consumer.

It is recommended that before proceeding with the installation of a gas piping system, a piping sketch or plan be prepared showing the proposed location and size of the piping and the various loads. Adequate consideration should be given to future loads and provisions made for added gas service.

Before any final plans or specifications are completed, the Gas Company or the proper administrative authorities should be consulted.

When additional equipment is to be served through existing piping, available capacity of the line shall be verified.

2.1.1 Locate Gas Piping Safely. Piping other than entry, shall not be buried underground inside of buildings. Avoid running piping through crawl spaces. Where gas piping must be run in crawl spaces, tunnels or unfrequented basements, continuous ventilation should be provided. See paragraphs 2.7.2, 2.7.3, 2.7.4.

Piping in crawl spaces should be treated in the same manner as other above ground piping with respect to painting and insulation if necessary. Entering piping buried inside the building beyond the wall must be encased in a protective pipe of larger diameter. It is recommended that such casing extend at least 4 in. outside of the building wall, being left open at that point, and sealed at the inside end of the casing and a removable threaded inspection plug be provided in the casing.

See Fig. 1, which illustrates an acceptable method of installing.

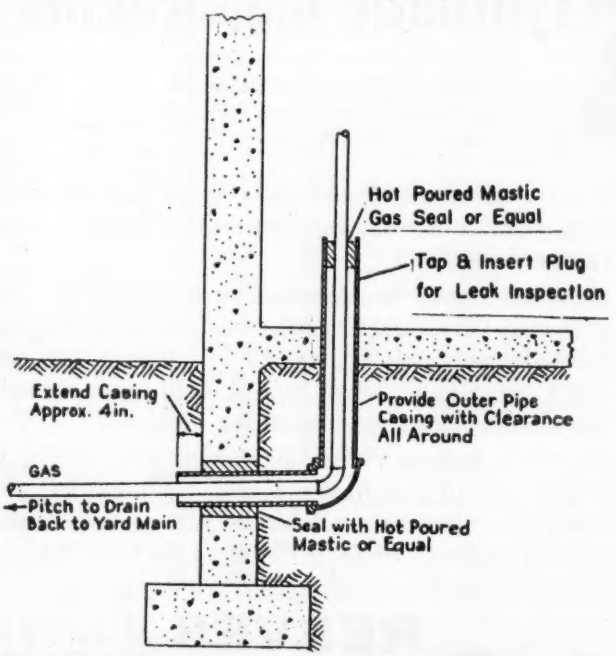

FIG. 1. Casing for gas pipe entrance buried under building with no crawl space.

When it is practical to do so, outdoor gas piping in industrial plant yards should be installed above ground. Such piping must be securely supported and located where it will be protected from physical damage. See 213 Section 2 ASA B31.1-1955. Where soil conditions are unstable and settling of piping or foundation walls may occur, adequate measures shall be provided to prevent excessive stressing of the piping. Avoid locating piping in cinder fill.

2.1.2 Preventing External Corrosion. Corrosion protection should be provided for all underground piping by any method or combination of methods where investigation indicates that such protection is needed. See 841.173 ASA B31.1.8-1955.

(Consult the local Gas Company relative to suggestions covering protection of underground piping.)

2.2 Installation of Consumer-Owned Gas Meters

2.2.1 Gas meters should be properly sized and designed for the maximum expected pressure.

2.2.2 Gas meters should be located in ventilated spaces readily accessible for examination, reading, replacement or necessary maintenance.

2.2.3 Gas meters shall not be placed where they will be subjected to damage, such as adjacent to a driveway, in public passages, halls, coal bins, etc., or where they will be subject to excessive corrosion.

2.2.4 Gas meters shall be located at least 3 ft from an unguarded flame or the possibility of electric sparks.

2.2.5 Gas meters shall not be located where they will be subjected to excessive temperatures or sudden extreme changes in temperature. Meter manufacturers will furnish information regarding safe temperature limits.

2.2.6 Gas meters shall be securely supported and connected to the piping so as not to exert a strain on the meters.

2.2.7 Where conditions are such as to produce condensate, a drip pot should be provided to prevent the condensate from entering the meter.

2.2.8 Gas meters, filters and strainers should be provided with suitably valved by-passes so that service may be maintained when it is necessary to calibrate or service them.

2.3 Consumer-Owned Gas Pressure Regulators

2.3.1 Where the gas supply pressure is higher than that at which the gas utilization equipment is designed to operate, a gas pressure regulator shall be installed. Where used, gas pressure regulators should maintain the gas pressure to the burner supply line within plus or minus 10 percent of the operating gage pressure between maximum and minimum firing rates. These limitations do not apply to regulators known as "zero governors" used in connection with gas-air proportioning and mixing systems.

Regulators of the spring loaded, dead weight or pressure balanced type are preferred. Spring, weight loaded or exposed lever type regulators must have springs, levers and weights covered by a suitable housing.

2.3.2 Pressure regulators of the diaphragm type, except zero governors, generally require venting. An adequately sized independent vent to a safe point outside the building should be provided when the regulator is such that a ruptured diaphragm will cause a hazard. Means should likewise be provided to prevent water, insects or foreign materials from entering the vent pipe.

2.3.3 Where failure of the pressure regulator could produce downstream pressures which might result in hazardous conditions or damage to equipment, the downstream piping system should be provided with adequate means for over-pressure protection.

2.3.4 Suitably valved by-passes should be placed around gas pressure regulators where continuity of service is imperative.

2.4 Materials

2.4.1 SELECT PROPER PIPE MATERIALS

Steel Pipe. Standard weight or ASA Schedule 40 Steel Pipe is acceptable and generally used for gas pressures up to 125 psig. For higher gas pressures, piping shall be selected in accordance with 214 ASA B31.1-1955.

Welded joints should be used wherever practical. (See Section 6, Chapter 4 of ASA B31.1-1955.) Compression or gland type fittings may be used if adequately braced so that neither the gas pressure nor external physical damage will force the joint apart. Pipe shall be fully inserted in gland or compression type joints before completing the assembly. Screw fittings should be mallea-

ble cast iron, steel castings or forgings. In sizes 4 in. and larger, cast iron fittings may be used.

Cast Iron Pipe. Cast iron pipe of 4 in. size and larger equipped with standardized mechanical joints and made in accordance with ASA specifications A21.7 or A21.9 may be used for underground service for pressures up to 50 psig. For provisions covering installations of cast iron pipe, refer to 842.2 ASA B31.1.8-1955.

Copper Pipe and Tubing. For gases containing sulfur compounds, copper and its alloys may prove unsuitable for gas piping. Consult the gas company before using these materials.

The use of copper tubing or piping shall comply with 847.4 ASA B31.1.8-1955, Copper Services (and Mains). For copper tubing, brazed (melting point over 1000 F) or flared joints should be used.

For copper and brass pipe, threaded or brazed joints (melting point over 1000 F) should be used. Compression or gland type couplings shall not be used in above ground installations.

2.4.2 Gasket Materials. Flange gaskets may be either of the full face or ring type, made from a standard grade asbestos or a composition sheet packing. Packing for gland type joints shall be of a material resistant to the action of LP gas or any other constituents of the gas to be handled. Consult the local gas company bearing in mind possible use of auxiliary or substitute gases during peak loads. For further information on gasket material specifications refer to 209(c)(2) ASA B31.1-1955.

2.4.3 Use of Old Pipe. Pipe, fittings, valves, etc., removed from any existing installation shall not be used again unless they have been thoroughly cleaned, inspected and ascertained to be equivalent to new material.

2.4.4 Joint Compounds. Joint compounds (pipe dope) shall be resistant to the action of liquefied petroleum gas or any other chemical constituents of the gases to be handled. Consult the local gas company bearing in mind possible use of auxiliary or substitute gases during peak loads.

2.4.5 Gas Pipe Identification. The use of a color coding to identify gas piping in accordance with ASA A13 "Identification of Piping Systems" is suggested.

2.5 Size of Piping

2.5.1 Capacity. Piping shall be of such a size and so installed as to provide a supply of gas sufficient to meet the requirements of demand and pressure at the point of use. The proper size depends upon the following factors:

a. Maximum gas consumption to be accommodated. See 2.5.2.
b. Diversity of load. See 2.5.3.
c. Allowable loss in pressure from the start of the pipe to the end. See 2.5.4.
d. Length of pipe, and number and size of fittings, valves, and control devices. See 2.5.5.
e. Specific gravity of the gas.
f. Allowance for any probable future change in consumption, specific gravity or heating value of gas.

2.5.2 Maximum Gas Consumption. The volume of gas to be provided for (in cu ft per hour) shall be determined directly from the manufacturer's input ratings of the equipment served. When input rating is not indicated, the gas company should be contacted for estimated volume of gas to be supplied.

To obtain the cu ft per hour of gas required, divide the Btu per hour rating by the average Btu per cu ft heating value of the gas supplied. The average heating value of the gas (Btu per cu ft) may be obtained from the local gas company.

2.5.3 Diversity of Load. Preferable practice is to use the total connected hourly load as the basis for pipe sizing since all equipment may be operating at full capacity simultaneously. However, if there is a diversity of load, smaller sized piping can be used with entire satisfaction.

2.5.4 Allowable Pressure Loss. It is recommended that the pressure loss in any gas piping system from the meter to any gas utilization equipment under maximum probable flow conditions should not exceed 0.5 in. water column for piping systems operating at ½ psig or less pressure, or 10 percent of the initial gage pressure for piping systems operating at higher pressures.

2.5.5 Equivalent Length of Pipe. Table I gives the Equivalent Resistance of Bends, Fittings, and Valves as Length of Straight Pipe in Feet to be added to the actual length to obtain the Total Equivalent Length on which pressure loss calculations are based.

To obtain the Total Equivalent Length add to the actual length of pipe involved the length in feet to allow for various fittings as shown in Table 1. Thus if the problem involves 300 ft of 6-in. pipe having three standard elbows and two gate valves, the Total Equivalent Length will be

$$300 + 3 \times 15.2 + 2 \times 3.54 = 352.68 \text{ ft.}$$

TABLE 1. Equivalent resistance of bends, fittings, and valves in length of straight pipe in feet.[1]

Nominal pipe size, inches	Inside pipe diameter, d, inches, Schedule 40	Screwed[3] Fittings				90° welding elbows and smooth bends						Miter Elbows[3] (No. of miters)					Welding Tees		Valves-screwed, flanged, or welded			
		45° Ell	90° Ell	180° close return bends	Tee	R/d =1	R/d =1½	R/d =2	R/d =4	R/d =6	R/d =8	1 45°	1 60°	1 90°	2 90°	3 90°	Forged	Miter	Gate	Globe	Angle	Swing Check
		L = equivalent length in feet of Schedule 40 (standard weight) straight pipe																				
½	0.622	0.73	1.55	3.47	3.10	0.83	0.62	0.47	0.36	0.47	0.62	0.78	1.55	3.10	1.04	0.78	2.33	3.10	0.36	17.3	8.65	4.32
¾	0.824	0.96	2.06	4.60	4.12	1.10	0.82	0.62	0.48	0.62	0.82	1.03	2.06	4.12	1.37	1.03	3.09	4.12	0.48	22.9	11.4	5.72
1	1.049	1.22	2.62	5.82	5.24	1.40	1.05	0.79	0.61	0.79	1.05	1.31	2.62	5.24	1.75	1.31	3.93	5.24	0.61	29.1	14.6	7.27
1¼	1.380	1.61	3.45	7.66	6.90	1.84	1.38	1.03	0.81	1.03	1.38	1.72	3.45	6.90	2.30	1.72	5.17	6.90	0.81	38.3	19.1	9.58
1½	1.610	1.88	4.02	8.95	8.04	2.14	1.61	1.21	0.94	1.21	1.61	2.01	4.02	8.04	2.68	2.01	6.04	8.04	0.94	44.7	22.4	11.2
2	2.067	2.41	5.17	11.5	10.3	2.76	2.07	1.55	1.21	1.55	2.07	2.58	5.17	10.3	3.45	2.58	7.75	10.3	1.21	57.4	28.7	14.4
2½	2.469	2.88	6.16	13.7	12.3	3.29	2.47	1.85	1.44	1.85	2.47	3.08	6.16	12.3	4.11	3.08	9.25	12.3	1.44	68.5	34.3	17.1
3	3.068	3.58	7.67	17.1	15.3	4.09	3.07	2.30	1.79	2.30	3.07	3.84	7.67	15.3	5.11	3.84	11.5	15.3	1.79	85.2	42.6	21.3
4	4.026	4.70	10.1	22.4	20.2	5.37	4.03	3.02	2.35	3.02	4.03	5.04	10.1	20.2	6.71	5.04	15.1	20.2	2.35	112.	56.0	28.0
5	5.047	5.88	12.6	28.0	25.2	6.72	5.05	3.78	2.94	3.78	5.05	6.30	12.6	25.2	8.40	6.30	18.9	25.2	2.94	140.	70.0	35.0
6	6.065	7.07	15.2	33.8	30.4	8.09	6.07	4.55	3.54	4.55	6.07	7.58	15.2	30.4	10.1	7.58	22.8	30.4	3.45	168.	84.1	42.1
8	7.981	9.31	20.0	44.6	40.0	10.6	7.98	5.98	4.65	5.98	7.98	9.97	20.0	40.0	13.3	9.97	29.9	40.0	4.65	222.	111.	55.5
10	10.02	11.7	25.0	55.7	50.0	13.3	10.0	7.51	5.85	7.51	10.0	12.5	25.0	50.0	16.7	12.5	37.6	50.0	5.85	278.	139.	69.5
12	11.94	13.9	29.8	66.3	59.6	15.9	11.9	8.95	6.96	8.95	11.9	14.9	29.8	59.6	19.9	14.9	44.8	59.6	6.96	332.	166.	83.0
14	13.13	15.3	32.8	73.0	65.6	17.5	13.1	9.85	7.65	9.85	13.1	16.4	32.8	65.6	21.9	16.4	49.2	65.6	7.65	364.	182.	91.0
16	15.00	17.5	37.5	83.5	75.0	20.0	15.0	11.2	8.75	11.2	15.0	18.8	37.5	75.0	25.0	18.8	56.2	75.0	8.85	417.	208.	104.
18	16.88	19.7	42.1	93.8	84.2	22.5	16.9	12.7	9.85	12.7	16.9	21.1	42.1	84.2	28.1	21.1	63.2	84.2	9.85	469.	234.	117.
20	18.81	22.0	47.0	105.	94.0	25.1	18.8	14.1	11.0	14.1	18.8	23.5	47.0	94.0	31.4	23.5	70.6	94.0	11.0	522.	261.	131.
24	22.63	26.4	56.6	126.	113.	30.2	22.6	17.0	13.2	17.0	22.6	28.3	56.6	113.	37.8	28.3	85.0	113.	13.2	629.	314.	157.

[1] Values for welding fittings are for conditions where bore is not obstructed by weld spatter or backing rings; if appreciably obstructed, use values for "Screwed Fittings."

[2] Flanged fittings have three-fourths the resistance of screwed elbows and tees (see reference (m) of footnote on p. 96).

[3] Small size socket-welding fittings are equivalent to miter elbows and miter tees.

TABLE 2a. Pipe sizing table for pressure under 1 lb.

*Approximate capacity of pipes of different diameters and lengths in cubic feet per hour with pressure drop of 0.5 in. water column and 0.6 specific gravity.

Iron Pipe Size Schedule 40 (Inches)	Total Equiv. Length of Pipe in Feet										
	50	100	150	200	250	300	400	500	1000	1500	2000
1	244	173	141	122	109	99	86	77	54	44	38
1¼	537	380	310	268	240	219	189	169	119	97	84
1½	832	588	480	416	372	339	294	263	185	151	131
2	1,680	1,188	970	840	751	685	594	531	375	306	265
2½	2,754	1,952	1,591	1,379	1,232	1,123	974	869	617	504	436
3	5,018	3,549	2,896	2,509	2,244	2,047	1,774	1,587	1,121	915	793
4	8,464	5,986	4,885	4,232	3,785	3,454	2,992	2,677	1,891	1,544	1,338
5	14,595	10,323	8,425	7,298	6,527	5,956	5,160	4,616	3,262	2,663	2,308
6	22,472	15,894	12,972	11,238	10,050	9,170	7,945	7,108	5,022	4,101	3,554
8	41,516	29,364	23,965	20,760	18,567	16,943	14,679	13,132	9,279	7,577	6,567

*Based on Spitzglass formula for pressures of less than 1 psig. For pressure drop of 0.3 in. wc multiply above by 0.775 or refer to Table 2 in Z21.30 which gives capacities up to 600 ft of length based on pressure drop of 0.30 an' is based on the Pole formula.

TABLE 2b. Pipe sizing table for 1 lb pressure.

Capacity of pipes of different diameters and lengths in cubic feet per hour. For an initial pressure of 1 psig with a 10 percent pressure drop and a gas of 0.6 specific gravity.

Pipe Size of Schedule 40 Standard Pipe (Inches)	Total Equiv. Length of Pipe in Feet										
	50	100	150	200	300	400	500	1000	1500	2000
1	740	520	430	370	300	260	230	170	130	120
1¼	1,540	1,090	890	760	630	540	490	350	280	250
1½	2,330	1,650	1,350	1,160	960	830	740	530	420	380
2	4,550	3,210	2,640	2,260	1,870	1,610	1,440	1,040	830	750
2½	7,330	5,180	4,250	3,650	3,020	2,600	2,320	1,690	1,340	1,200
3	13,100	9,260	7,600	6,520	5,400	4,660	4,160	3,020	2,400	2,160
3½	19,320	13,650	11,210	9,610	7,960	6,870	6,130	4,450	3,540	3,180
4	26,980	19,070	15,650	13,430	11,120	9,590	8,560	6,220	4,940	4,440
5	49,340	34,870	28,620	24,550	20,330	17,550	15,660	11,370	9,030	8,130
6	80,560	56,940	46,740	40,090	33,210	28,650	25,580	18,570	14,760	13,280

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TABLE 2c. Pipe sizing table for 2 lb pressure.

Capacity of pipes of different diameters and lengths in cubic feet per hour. For an initial pressure of 2 psig with a 10 percent pressure drop and a gas of 0.6 specific gravity.

Pipe Size of Schedule 40 Standard Pipe (Inches)	Total Equiv. Length of Pipe in Feet										
	50	100	150	200	300	400	500	1000	1500	2000
1	1,080	760	620	540	440	380	340	240	190	170
1¼	2,250	1,580	1,300	1,120	910	790	710	500	410	350
1½	3,410	2,410	1,970	1,700	1,390	1,200	1,070	760	620	530
2	6,640	4,700	3,840	3,310	2,700	2,350	2,090	1,480	1,210	1,040
2½	10,700	7,580	6,190	5,340	4,360	3,790	3,380	2,390	1,960	1,690
3	19,120	13,540	11,060	9,540	7,790	6,770	6,040	4,280	3,500	3,020
3½	28,200	19,970	16,310	14,070	11,490	9,980	8,900	6,310	5,160	4,450
4	39,380	27,890	22,780	19,650	16,040	13,940	12,440	8,810	7,210	6,220
5	72,010	50,990	41,650	35,930	29,300	24,490	22,740	16,120	13,180	11,370
6	117,580	83,270	68,010	58,670	47,900	41,630	37,140	26,320	21,520	18,570

TABLE 2d. Pipe sizing table for 5 lb pressure.

Capacity of pipes of different diameters and lengths in cubic feet per hour. For an initial pressure of 5 psig with a 10 percent pressure drop and a gas of 0.6 specific gravity.

Pipe Size of Schedule 40 Standard Pipe (Inches)	Total Equiv. Length of Pipe in Feet									
	50	100	150	200	300	400	500	1000	1500	2000
1	1,860	1,320	1,070	930	760	660	590	410	340	290
1¼	3,870	2,740	2,240	1,930	1,580	1,370	1,220	860	700	610
1½	5,860	4,140	3,390	2930	2,390	2,080	1,850	1,310	1,060	930
2	11,420	8,070	6,600	5,710	4,660	4,050	3,610	2,550	2,080	1,810
2½	18,400	13,010	10,640	9,200	7,510	6,530	5,820	4,110	3,350	2,920
3	32,860	23,240	19,000	16,430	13,410	11,660	10,390	7,340	5,990	5,220
3½	48,480	34,280	28,030	24,240	19,780	17,200	15,330	10,820	8,840	7,690
4	67,700	47,880	39,140	33,850	27,630	24,020	21,410	15,120	12,340	10,750
5	123,790	87,540	71,570	61,890	50,530	43,920	39,160	27,640	22,570	19,660
6	202,138	142,950	116,870	101,060	82,500	71,720	63,940	45,140	36,860	32,100

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TABLE 2e. Pipe sizing table for 10 lb pressure.

Capacity of pipes of different diameters and lengths in cubic feet per hour. For an initial pressure of 10 psig with a 10 percent pressure drop and a gas of 0.6 specific gravity.

Pipe Size of Schedule 40 Standard Pipe (Inches)	Total Equiv. Length of Pipe in Feet									
	50	100	150	200	300	400	500	1000	1500	2000
1	2,930	2,070	1,690	1,470	1,190	1,030	920	650	530	460
1¼	6,090	4,330	3,520	3,050	2,490	2,150	1,920	1,360	1,110	960
1½	9,210	6,530	5,330	4,620	3,760	3,260	2,910	2,060	1,680	1,460
2	17,940	12,720	10,380	9,000	7,330	6,360	5,680	4,020	3,280	2,840
2½	28,920	20,500	16,730	14,510	11,820	10,250	9,150	6,480	5,290	4,580
3	51,650	36,610	29,880	25,920	21,110	18,300	16,340	11,570	9,450	8,190
3½	76,180	53,990	44,070	38,240	31,140	26,990	24,110	17,070	13,950	12,080
4	106,400	75,410	61,550	53,410	43,500	37,700	33,670	23,850	19,840	16,870
5	194,540	137,890	112,550	97,650	79,540	68,940	61,570	43,600	35,620	30,860
6	317,650	225,150	183,770	159,450	129,870	112,560	100,540	71,200	58,160	50,390

TABLE 2f. Pipe sizing table for 20 lb pressure.

Capacity of pipes of different diameters and lengths in cubic feet per hour. For an initial pressure of 20 psig with a 10 percent pressure drop and a gas of 0.6 specific gravity.

Pipe Size of Schedule 40 Standard Pipe (Inches)	Total Equiv. Length of Pipe in Feet									
	50	100	150	200	300	400	500	1000	1500	2000
1	4,900	3,470	2,810	2,450	2,000	1,730	1,550	1,070	890	770
1¼	10,190	7,210	5,840	5,090	4,160	3,600	3,220	2,230	1,860	1,610
1½	15,420	10,900	8,830	7,710	6,290	5,450	4,870	3,370	2,810	2,440
2	30,030	21,230	17,190	15,010	12,260	10,610	9,490	6,570	5,480	4,760
2½	48,390	34,220	27,710	24,190	19,750	17,110	14,290	10,590	8,830	7,670
3	86,420	61,110	49,490	43,190	35,280	30,550	27,310	18,910	15,770	13,690
3½	127,480	90,130	73,000	63,710	52,040	45,070	40,280	27,900	23,270	20,200
4	178,040	125,880	101,950	88,980	72,680	62,940	56,260	38,960	32,500	28 210
5	325,530	230,170	186,410	162,700	132,890	115,080	102,870	71,240	59,420	51,590
6	531,530	375,820	304,370	265,660	216,990	187,910	167,980	116,330	97,030	84,240

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TABLE 2g. Pipe sizing table for 50 lb pressure.

Capacity of pipes of different diameters and lengths in cubic feet per hour. For an initial pressure of 50 psig with a 10 percent pressure drop and a gas of 0.6 specific gravity.

Pipe Size of Schedule 40 Standard Pipe (Inches)	Total Equiv. Length of Pipe in Feet										
	50	100	150	200	300	400	500	1000	1500	2000
1	10,530	7,450	6,090	5,150	4,350	3,790	3,330	2,350	1,920	1,650
1¼	21,880	15,490	12,650	10,700	9,050	7,870	6,920	4,890	3,990	3,430
1½	33,110	23,430	19,130	16,190	13,690	11,910	10,470	7,410	6,040	5,190
2	64,450	45,610	37,250	31,530	26,660	23,190	20,400	14,420	11,770	10,110
2½	103,870	73,510	60,040	50,820	42,960	37,370	32,870	23,240	18,970	16,300
3	185,490	131,270	107,220	90,750	76,720	66,730	58,700	41,510	33,870	29,100
3½	273,600	193,620	158,140	133,850	113,170	98,430	86,590	61,230	49,970	42,930
4	382,110	270,420	220,870	186,940	158,050	137,480	120,930	85,510	69,780	59,960
5	698,660	494,430	403,840	341,800	288,980	251,360	221,110	156,360	127,600	109,630
6	1,140,780	807,320	659,400	558,110	471,860	410,430	361,040	255,310	208,340	179,010

TABLE 3. Multipliers to be used with Tables 2a-2g when the specific gravity of the gas is other than 0.60.

Specific Gravity	Multiplier	Specific Gravity	Multiplier
.35	1.31	1.00	.775
.40	1.23	1.10	.740
.45	1.16	1.20	.707
.50	1.10	1.30	.680
.55	1.04	1.40	.655
.60	1.00	1.50	.633
.65	.962	1.60	.612
.70	.926	1.70	.594
.75	.895	1.80	.577
.80	.867	1.90	.565
.85	.841	2.00	.547
.90	.817	2.10	.535

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See Table 3 to compensate for specific gravity other than 0.60.

2.5.6 Piping Tables. The pipe sizing Tables (2a to 2g) giving the Total Equivalent Length of Pipe in Feet, indicate approximate capacities for single runs of piping. Where more complex systems are involved, detailed engineering calculations must be made.

2.5.7 Extensions. The size of extensions to existing piping systems should be calculated in accordance with the rules established by Section 2.5.1 but in no case should extensions be made to existing pipe which are smaller than those determined through the use of Piping Tables described in Section 2.5.6.

2.6 Pipe Threads

2.6.1 Specifications for Pipe Threads. Pipe and fitting threads shall comply with the American Standard for Pipe Threads, ASA B2.1-1945, a portion of which follows:

Nominal Pipe Size (Inches)	Approximate Length of Threaded Portion (Inches)	Approximate No. of Threads to be Cut
¾	¾	10
1	⅞	10
1¼	1	11
1½	1	11
2	1	11
2½	1½	12
3	1½	12
4	1⅝	13
6	1¾	14
8	2	16

2.6.2 Damaged Threads. Pipe with threads which are stripped, chipped, corroded or otherwise damaged shall not be used. If a weld opens during the operation of cutting or threading, that portion of the pipe shall not be used.

2.7 Concealed Piping

General: Concealed gas piping may become hazardous if any leakage develops. The hazard is greatly increased at higher gas pressures.

Concealed piping should be avoided.

Where concealment can not be avoided every possible precaution should be taken to limit the hazard. These precautions should include the following:

2.7.2 Piping Locations. Gas piping should not be run in floors or solid partitions of buildings, or through heating, cooling or ventilating ducts, elevator shafts, furnaces, refrigerating rooms, drying ovens or in any place where proper ventilation cannot be continuously provided and piping easily inspected at any time.

Piping may be run in separate shafts, pipe ways, channels or trenches if these are properly ventilated at all times and easily opened for inspection throughout their length.

2.7.3 Installation of Concealed Piping. When installing gas piping that must be concealed, all threaded or flanged joints shall be made permanently tight. If possible use welded joints. Do *not* use unions, gland or compression type joints, running threads, right and left couplings, bushings, and swing joints including those made by combinations of fittings except as covered by paragraph 2.7.4.

2.7.4 Reconnections. When necessary to insert fittings in existing piping which has been installed in a concealed location, the piping may be reconnected by the use of a ground joint union with the nut "center punched" to prevent loosening by vibration.

2.8 Installation of Piping and Fittings

2.8.1 Building Structure. The building structure shall not be weakened by the installation of any gas piping. Before any structural members are cut or notched, special permission should be obtained from the proper administrative authority.

2.8.2 Piping Subjected to Low Temperatures. Natural gas is usually dry and thus is not subject to freezing. Occasionally gas companies find it necessary to steam fog natural gas. When this is practiced, piping shall be treated to prevent gas from freezing. Manufactured gas and mixed gas generally contain moisture and therefore the piping should be buried at least 24-in. or should be well insulated when installed above ground. Consult the local gas company.

When it is necessary to install piping on or along an outside wall, furring strips shall be placed between the piping and the wall. If lines carrying gases having appreciable moisture content may be subjected to low temperatures, the piping should be protected with a suitable covering of insulation or such other precautions taken as may be necessary to prevent freezing.

2.8.3 Condensate in Piping. Piping carrying gases containing moisture or other condensibles shall be properly graded to risers, drips, or to a suitable collecting point at the gas utilization equipment. The pitch shall be no less than ¼-in. in 15 ft and there shall be no traps in the piping.

Except where a dry gas is used, a drip of adequate size shall be provided at any point in the line of piping where a condensate may collect. The size of any drip shall not be smaller than the diameter of the pipe to which it is attached and shall be installed where it can be readily emptied and cleaned. Drips shall not be located where the condensate is likely to freeze. Where expedient for the removal of condensate and scale, a "T" with its bottom opening extended and capped should be located at each low point in the line. See 211 ASA B31.1-1955.

2.8.4 Supporting Pipe. All gas piping shall be securely fastened to structural members of adequate strength and supported with pipe hooks, metal pipe straps, bands or hangers of the proper strength and quality for the size of pipe and located at proper intervals. Gas piping shall not be hung, strapped or otherwise supported from a water, steam, sewer or other pipe or electric conduit.

Spacing of supports in piping installations shall not be greater than the following:

¾ in. or 1 in. pipe ..... 8 ft
1¼ in. or larger (horizontal) ..... 10 ft
1¼ in. or larger (vertical) ..... every floor level

2.8.5 Bending Pipe. Where pipe bends are the only practical way to provide changes in direction, they should be made in such a way that they shall be free from buckling, cracks or other evidence of physical damage and the effective gas carrying capacity shall not be materially reduced.

2.8.6 Provision for Expansion. Long runs of pipe of 4 in. diameter and over may require suitable means to compensate for expansion and contraction. For details see Chapter 3, Section 6 of ASA B31.1-1955.

2.8.7 Closing Pipe Openings. All outlets including valve or plug cock outlets shall be made gas tight with pipe caps, pipe plugs, or blind flanges until the gas utilization equipment has been connected. Likewise, when equipment is disconnected from an outlet and the outlet is not to be used again immediately, it shall be securely closed as indicated above. In no case shall the outlets be closed with wooden plugs, corks, tin caps, etc.

2.8.8 Branch Piping Connections. All branch connections should preferably be taken from the top or sides of horizontal lines. See Chapter 5, Section 6, ASA B31.1-1955.

2.8.9 Bushings. Reducing couplings are to be preferred to bushings. Cast iron or plastic bushings should not be used. When bushings must be used they should reduce no less than two pipe sizes, otherwise their wall thickness is inadequate.

2.9 Gas Shut-Off Valve

2.9.1 Shut-Off Valves. Shut-off valves or cocks should be selected giving consideration to pressure drop and service involved. Full opening lubricated plug valves or gate valves cause minimum pressure drop. Where cocks are used in sizes larger than 2 in., or for pressures greater than ½ psig, the lubricated plug type cock is recommended. Where pressures of 5 psig or greater are used Tamper-Proof Cocks are recommended.

Manual shut-offs should be provided at appropriate points in large piping systems and also at each oven, furnace or other integral piece of gas utilization equipment. It is advisable to provide an exterior shut-off to permit cutting off the gas supply to each building in an emergency. The emergency shut-off valves should be plainly marked as such and their locations posted at appropriate points.

2.10 Test of New Piping for Tightness

2.10.1 Final Testing and Inspection. Before the piping is finally approved and equipment or gas supply is connected, a test for tightness shall be made by the installer and observed by a qualified representative of the authority responsible for final approval.

To test for tightness, the system shall be subjected to a test pressure of at least 1.5 times the proposed maximum operating pressure, but never less than 6-in. of mercury column or 3 psig. The system shall hold this bottled up pressure after disconnecting the pressure source for a period of time depending upon the size of the system, but not less than 10 minutes, without showing any

drop in pressure after the test gas in the pipe has been given time to arrive at the ambient temperature.

Unusually long piping systems of larger diameter pipe to be used at pressures above ½ psig should be tested for longer periods of time.

2.10.2 Test Gas. For test purposes, air or an inert gas such as carbon dioxide, nitrogen or combustion products should be used as the pressurizing medium. UNDER NO CIRCUMSTANCES SHALL OXYGEN OR ETHER BE USED TO TEST FOR TIGHTNESS OR TO LOCATE LEAKS.

2.10.3 Locating Leaks. Tests for leaks should be made with approved leak detectors or by brushing on a soap and water solution or its equivalent while the system is under pressure.

2.11 Turning On Gas

2.11.1 Turning on Gas. When the accredited representative of the authority having jurisdiction is satisfied the piping system is free of leakage, the gas may be turned on and service established.

2.11.2 Before gas is turned into a system of new gas piping, or back into an existing system after being shut off, the entire system shall be checked to make certain that there are no open fittings or ends and that all valves at outlets and equipment are closed.

2.11.3 Checking for Leakage with Meter. Immediately after turning the gas into the piping system, the system shall be checked to ascertain that no gas is escaping. If a meter is available this can be done by carefully watching the test dial to determine whether gas is passing through the meter. The observation should be made with the test hand on the "upstroke."

2.12 Purging

2.12.1 Purge All Gas Lines. After the piping system has been leak tested and pressure tested, it should be fully purged at the most distant point from the point of entry of the gas by a hose or temporary pipeline to the outside of the building. Each major branch line should be similarly purged at its far end. The AGA Purging Handbook describes details of purging methods.

PART III — INSTALLATION OF GAS EQUIPMENT ON INDUSTRIAL AND COMMERCIAL PREMISES

3.1 General

It is intended that all gas equipment installed under these standards shall be safe and suitable for the conditions under which it is to be used.

It is recommended that the person or agency authorizing the installation of the gas equipment make use of the applicable national equipment standards. In applying these installation standards, reference should be made also to gas equipment manufacturers' instructions, gas company regulations, and local building, plumbing, gas and steam fittings codes or other applicable regulations in effect in the area in which the installation is to be made.

Gas equipment not covered by standards or specifications listed herein may be investigated, or tested after installation, to demonstrate that it is safe and suitable for the proposed service, and that it is recommended for that service by the manufacturer.

3.1.1 Type of Gas. It shall be determined that the gas equipment has been designed for use with the type of gas available at the point of utilization. No attempt shall be made to convert the equipment from the gas specified on the rating plate for use with a different gas without consulting the gas supplier and/or the equipment manufacturer for complete instructions.

3.1.2 Verification of Gas Supply. When planning the installation of additional gas equipment the gas supplier should be consulted to determine the adequacy of the gas supply, piping, and meter set assembly. See 2.1, 2.5, and 3.2.1.

3.1.3 Use of Air or Oxygen Under Pressure. When gas equipment is to be installed which may permit air, oxygen, or other gases to flow into the gas supply lines suitable provisions shall be made to prevent such flow. See 846.32 in ASA B31.1.8-1955 and NFPA—NBFU Pamphlet No. 51-1956, Section 34.

3.1.4 Installation Instructions. The installer and/or gas equipment manufacturer shall furnish installation instructions which shall be followed in making the installation and which shall be left in a location on the premises where they are readily available for reference.

3.2 Areas of Responsibility

Because industrial and commercial gas applications are so varied in nature, many agencies are jointly responsible for their safe and satisfactory use. The general areas of responsibility are outlined in this section and a detailed check-list given.

3.2.1 The Person or Agency Planning an Installation of Gas Equipment Is Normally Responsible for:

Verifying the adequacy of the gas supply, volume and pressure,
Determining suitability of gas for the process, and
Notifying gas suppliers of significant changes in requirements.

3.2.2 The Gas Supplier Is Normally Responsible for Furnishing the User, Upon Request, with Complete Information on:

Combustion characteristics and physical-chemical properties such as specific gravity, heating value, pressure, and the approximate analysis of the gas.

Conditions under which an adequate supply of gas at suitable pressure can be brought to the site, and
Continuity of the gas supply.

3.2.3 The Gas Equipment Manufacturer or Builder Is Normally Responsible for:

Design and construction of all gas equipment or assemblies shipped from his plant,

Design and construction of all gas equipment fabricated, erected, or assembled by him in the field.

A statement of the maximum hourly Btu input, type of gas, and design pressure range, and
Operating instructions for the user.

3.2.4 The Person or Agency Making and/or Authorizing the Installation of Gas Equipment Is Normally Responsible for:

The selection, erection, and/or assembling of gas equipment, components, or designs purchased or developed by him,

Conforming to codes, ordinances, or regulations applicable to the installation,

Adequacy of necessary vents and chimneys, and

Maintaining and operating the gas equipment in a safe manner at all times.

3.2.5 Gas Equipment Design and Construction Check-List. The following check-list, 3.2.5.1 to 3.2.5.7, should be considered by those responsible for the design or selection of the equipment.

3.2.5.1 Basic Design and Installation Factors

Suitability of equipment for process requirements,
Adequate structural strength and stability,
Reasonable life expectation,
Conformance to existing safety standards,
Adequate combustion space and venting, and
Means for observation and inspection of combustion.

3.2.5.2 Materials of Construction: Materials used should provide reasonable life expectancy for the service intended and be capable of satisfactorily withstanding:

Operating temperatures,
Chemical action,
Thermal shock, and
Load stresses.

3.2.5.3 Combustion Systems. Combustion systems should be selected for the characteristics of the available gas so that they will operate properly at the elevation at point of use and produce:

Proper heat distribution,
Adequate operating temperature range,
Suitable flame geometry,
Flame stability,
Operating flexibility, and
Desired heating chamber atmosphere.

3.2.5.4 Pipe, Fittings and Valves. Pipe, fittings and valves should conform to applicable ASA standards and to Sections I and II of Information Letter No. 70-1955. Concealed piping, bushings, material in fittings, etc., should not be selected nor used until the following factors have been considered:

Correct size to handle required volume (Consideration of pressure drop in controls and manifolds is particularly important in low-pressure systems),

Material specifications suitable for pressures and temperatures encountered,

Adequate supports and protection against physical damage,

Tight assembly and thorough leak inspection,

Use of sufficient unions and flanges, where permitted, for convenient field replacement or repair, and

Arrangement of piping to provide accessibility for equipment adjustments and freedom from thermal damage.

3.2.5.5 Fuel and Electrical Information. Information concerning the characteristics of the gas and electricity available at the point of utilization should be specific and complete. Gas controls and electrical equipment should be selected to conform to these characteristics. Specifications to consider include:

Type of gas: Heat content, pressure, specific gravity, and approximate analysis,

Voltages, phase, cycles for both control and power circuits,

Location of electrical equipment and wiring to avoid thermal damage and excessive concentrations of dust, dirt, or foreign material, and

Applicable electrical codes and/or standards.

3.2.5.6 Temperature Controls. Temperature controls, if used, should be carefully selected considering:

Range and type of instruments and sensing elements,

Type of control action,

Suitability for service required, and

Correlation of control instruments with operating equipment.

3.2.5.7 Protective Equipment. In enclosed chambers the accumulation of gas-air or solvent-air mixtures, which may be accidentally ignited, constitutes a potential hazard to life and property. For this reason it is necessary to select and install suitable protective equipment. The selection of a satisfactory protective system and components not otherwise covered by existing codes or standards should be based on the requirements of each individual installation after consultation with the various interested parties, including user, designer, insurance company, and local authorities having jurisdiction.

Some of the factors and considerations involved in the selection of protective equipment are:

Feasibility of its installation,

Its adaptability to process and control requirements,

Conformance to existing standards, ordinances, requirements, and other regulations which apply.

3.3 Location of Equipment

Gas equipment, and flue or vent connectors when required, shall be installed in a location where continuous or intermittent operation (whichever is required) will not create a hazard to persons or property.

3.3.1 Accessibility for Service and Repairs. The location of gas equipment should be such as to make it accessible for adjusting, cleaning, and servicing of burners, motors, controls, draft hoods, and other working parts, without extensive disassembly.

3.3.2 Air Supply for Combustion, Processes, and Ventilation. Gas equipment shall be installed in a location where the facilities for ventilation permit satisfactory combustion of gas and proper venting under normal conditions of use. (See 3.5.)

3.3.3 Venting Requirements. Adequate provisions shall be available for the safe removal of combustion products, process fumes, and used ventilating air. (See Venting 3.6.)

3.3.4 Mounting Requirements. At locations selected for installation of gas equipment the dynamic and static load carrying capacities of the building structure should be checked to determine if they are adequate to carry the additional loads.

Gas equipment shall be adequately supported and so connected to the piping as not to exert undue stress on the connections.

The building structure shall be adequately protected against thermal damage where it may be endangered by heat and against impact damage from material being carried on conveyors or by pieces falling from conveyors.

3.3.5 Building Structures and Clearances

3.3.5.1 Inclusion of the building columns, girders, beams, or trusses within gas equipment shall not be considered unless appropriate insulation and ventilation can be provided to avoid all deterioration in strength caused by heat, ignition of combustible materials, and detrimental linear expansion of the building structure.

In any installation, structural members of a building shall not pass through the gas equipment if the operating temperature is to be in excess of 500 F. If structural members of a building are to pass through gas equipment having an operating temperature less than 500 F., but in excess of 160 F., they shall be noncombustible or fireproofed.

For suitable methods of fireproofing, see the National Building Code of the National Board of Fire Underwriters or the building code of the locality in which the building is located.

3.3.5.2 Gas Equipment should be located where it will easily be accessible with adequate clearance available above the equipment to permit inspection and maintenance, installation of automatic sprinklers, proper use of firehose streams, and proper functioning of explosive vents. Exterior surfaces of gas equipment shall be sufficiently insulated and the surrounding space sufficiently ventilated to keep temperatures of adjacent combustible structures below 160 F. See NFPA - NBFU Bulletin No. 86, Class A Ovens and Furnaces, for detailed recommendations. Though these pamphlets apply to ovens and furnaces, many provisions therein apply equally to other gas equipment.

3.3.6 Supports. Gas equipment should be furnished either with load distributing bases, or with a sufficient number of adequate supports to prevent damage to either building structure or equipment.

3.3.7 Gas Equipment Barricades. When it is necessary to locate gas equipment close to a passageway traveled by trucks or cranes, suitable guard rails or bumper plates should be installed to protect the equipment from damage.

3.3.8 Portable Gas Equipment. Portable gas equipment on wheels should be equipped with suitable bearings and heat shields so that exposure to operating temperatures will not cause wheels to lock or move with difficulty.

Portable gas equipment designed to be moved with lift trucks should be equipped with bumper guards to prevent damage from normal impact by the truck.

Portable gas equipment intended for placement and operation above floor level (such as hand torches, counter appliances, etc.) shall be securely supported.

3.4 Connection to Building Gas Piping

3.4.1 Rigid and Semi-Rigid Connectors.

3.4.1.1 Gas equipment, except equipment which requires mobility for operation, equipment subject to vibration, or equipment used in more than one location, shall be connected to the building gas piping system with rigid piping of proper size and material.

When installation conditions require, minimum lengths of semi-rigid piping may be used. Refer to Sections 2.4 and 2.5 for proper pipe size and materials.

3.4.1.2 Connections to building gas piping should be made at the top or sides of horizontal lines.

3.4.1.3 All connections shall be protected from physical or thermal damage.

3.4.2 Flexible Connections

3.4.2.1 General. Where flexible connections are used, they shall be of the minimum practical length and shall not extend from one room to another nor pass through any walls, partitions, ceilings, or floors. Flexible connections shall not be used in any concealed location. They shall be protected against physical or thermal damage and shall be provided with gas shut-off valves, in readily accessible locations, in the rigid piping upstream from the flexible connections.

3.4.2.2 Flexible Connectors — All Metal. Gas equipment requiring mobility for operation or subject to vibrations may be connected to the building piping system by the use of all metal flexible connectors suitable for the service required.

3.4.2.3 Swivel Joints or Couplings. Gas equipment requiring mobility may be connected to the rigid piping by the use of swivel joints or couplings which are suitable for the service required. Where swivel joints or couplings are used, only the minimum number required shall be installed.

3.4.2.4 Flexible Hose — Not All Metal. Portable gas equipment may be connected to the building gas piping system by the use of flexible hose suitable and safe for the conditions under which it may be used.

Hose used to connect oxy-gas torches shall comply with the requirements of NFPA-NBFU Pamphlet No. 51-1956, Section 36.

3.5 Air Requirements

The air requirements of the gas equipment to be installed and the air supply in the building in which the equipment is to be installed shall be checked to determine that sufficient air is available. If normal air infiltration is inadequate, sufficient new or

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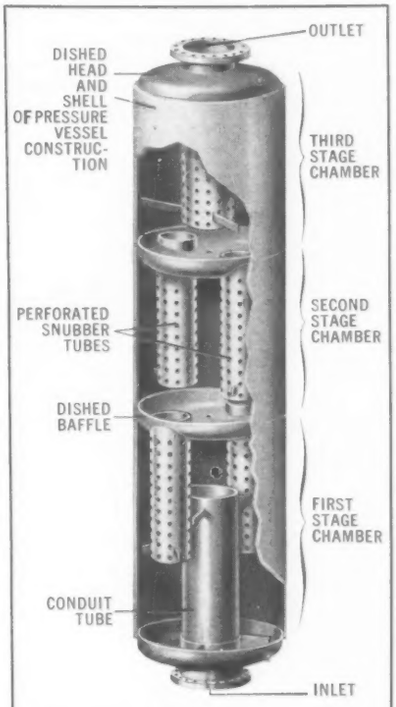

DESIGN—Silencing is achieved as the exhaust or intake slug passes through a series of non-reactive ported tubes and snubbing chambers. Noise is actually prevented—not muffled. Same principle applies to pulsation snubbers within a pressure piping system.

PULSATION SNUBBERS

. . . scientifically engineered to reduce damaging vibration caused by surge and pulsation of the flow stream from compressors, pumps, or blowers. Snubbers are recommended and designed upon the basis of compressor and operating data obtained by our field engineering representatives. When necessary, our specialists conduct on-location pulsation surveys, using special electronic equipment developed for our particular engineering approach to pulsation control. Data on the pulsation amplitude and observation of pipe vibration are compiled and analyzed, and presented in a technical report with recommendations on the type of snubber required. (Typical reports are available upon request.) Pulsation snubbers are usually recommended for installation at the suction and discharge side of each stage of compression, close-coupled to the cylinder. All compressible media such as air, gases, nitrogen, ammonia, etc., can be handled, and snubbers can be built to all code requirements. Pulsation snubbers have been installed to operate with gases from 2.016 to 120 molecular weight on single- and multi-cylinder and multi-stage compressors, from full vacuum to 23,000 p.s.i. working pressures. We can design units for any required working pressures. Applications include installation in any closed piping system handling air or gas under pressure.

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EMERGENCY BLOW-DOWN SILENCERS

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SPECIFICATIONS

Owing to limited space, it is impracticable to list herein the wide range of available types and sizes of our full line of silencers, pulsation snubbers, and special units. However we shall be glad to furnish complete details without obligation if you will contact our general offices in Dallas, or we shall be glad to have one of our sales engineering representatives (available world-wide) call upon you either at your office or at a plant or field location. Your inquiry is welcomed.

DISTRICT SALES OFFICES: NEW YORK BR 9-9418. LIBERTYVILLE EM 2-1800 (CHICAGO BR 4-5901). DALLAS FL 7-1525. LOS ALAMITOS GE 1-7384.

make-up air shall be supplied to prevent any possibility of creating a partial vacuum in the building. Suitable precautions should be taken to assure that the air supply will be clean. When necessary, make-up air should be heated. (See 3.6.1.1.)

3.5.1 Combustion. Complete combustion of gas requires approximately one cubic foot of air, at standard conditions, per 100 Btu of fuel burned, but additional air for proper burner operation (atmospheric burner) may be required.

In the case of unusually tight construction, the building space in which gas equipment is installed may not have adequate air infiltration to assure proper combustion. One or more permanent openings to the out-of-doors or to spaces freely communicating to the out-of-doors are required. Such openings shall have a minimum area of 1 sq in. for every 2500 Btu per hr for equipment with draft hoods. For other equipment an opening or openings having a minimum area of 0.5 sq ft per 1,000,000 Btu per hr should be provided.

3.5.2 Process Air. Process air may be required for:

Cooling equipment or material,
Controlling dew point,
Heating, drying, oxidation, or dilution,
Safety exhaust,
Draft hood operation,
Odor control, and
Compressors.

3.5.3 Ventilation. Air requirements for ventilation include all air required for comfort and proper working conditions for personnel.

3.6 Venting

Venting, for the purposes of this standard, is defined as removal of combustion products as well as noxious or toxic process fumes to the outer air by means of roof openings, natural draft chimneys, flue stacks, or mechanical exhaust systems.

Responsibility for the proper venting of industrial types of gas-burning equipment shall rest with the person or agency making and/or authorizing the installation. Local applicable air pollution regulations shall be followed.

3.6.1 Requirements for Venting. Venting systems shall conform to the following specific requirements and to those of the authority having jurisdiction. Hoods may be used in place of direct flue connections, particularly when the process itself requires fume disposal.

3.6.1.1 Removal of Products of Combustion. When located in a large and well ventilated space, industrial gas equipment may be operated by discharging the products of combustion directly into the space, subject to the approval of the authority having jurisdiction, provided that the maximum input of the equipment shall not exceed 30 Btu per hr for each cu ft of enclosed space in which the equipment is located. Residential and commercial gas appliances installed in office, laboratory, cafeteria spaces, and related portions of industrial occupancies shall be vented in accordance with Part V of ASA Z21.30-1954.

3.6.1.2 Removal of Gases Other than Products of Combustion. Where toxic, corrosive, or flammable process fumes are present suitable means for their safe disposal must be provided. Such fumes include carbon monoxide, hydrogen, sulfide, ammonia, chlorine, cyanide, lead, carbon tetrachloride, zinc, and beryllium.

3.6.2 Draft Control for Vent Connected Gas Equipment

3.6.2.1 Draft Hoods. Draft hoods of approved types shall be installed on vented gas equipment, except incinerators, units designed for blast or pressure burners, units designed for forced venting, and units requiring chimney draft for operation. See ASA Z21.30-1954 for approved types of draft hoods.

3.6.2.1.1 Installation of Draft Hoods. Where the draft hood is part of the gas equipment or is supplied by the equipment manufacturer, it shall be installed without alteration in accordance with the manufacturer's instructions. In the absence of manufacturer's instructions, the draft hood shall be attached to the flue collar of the equipment or as near to the equipment as conditions permit. In no case shall a draft hood be installed in a false ceiling, in a different room, or in any place or manner that will permit a difference in pressure between the draft hood relief opening and the combustion air supply.

3.6.2.1.2 Position of Draft Hood. A draft hood shall be installed in the position for which it was designed with reference to the horizontal and vertical planes and shall be so located that the relief opening is not obstructed by any part of the gas equipment or adjacent construction.

3.6.2.2 Barometric Draft Regulators. Flue connected gas equipment requiring controlled chimney draft may be equipped with a suitable barometric type draft regulator. To relieve occasional back draft, double acting barometric draft regulators are usually preferred. A device which will automatically shut off the gas to the burner in the event of sustained back draft is recommended when it might adversely affect burner operation or when flue gas spillage might introduce a hazard.

3.6.2.3 Automatic Damper Regulators. Automatic damper regulators shall be interlocked with gas burner control systems to prevent hazardous operation in event of mechanical failure.

3.6.2.4 Manual Stack Dampers in Converted Equipment. When equipment is converted from other fuels to gas, manual stack dampers shall be fixed to prevent change in position and provided with a minimum opening or position to assure adequate venting of combustion products.

3.6.2.5 Installation of Draft Control Devices. Where a draft control device is part of the gas equipment or is supplied by the equipment manufacturer, it shall be installed without alteration in accordance with the manufacturer's instructions. In the absence of manufacturer's instructions, the device shall be attached to the flue collar of the equipment or as near to the equipment as conditions permit. In no case shall a draft control device be installed in a false ceiling, in a different room, or in any place or manner that will permit a difference in pressure between the draft relief opening and the combustion air supply.

A draft control device shall be installed in the position for which it was designed with reference to the horizontal and vertical planes and shall be located so that the relief opening is not obstructed by any part of the gas equipment or adjacent construction.

Where mechanical exhausters or induced or forced draft devices are used, provision shall be made to prevent flow of gas to the burners upon failure of these devices.

3.6.3 Vent Connectors (Flue Connectors or Breechings)

3.6.3.1 Vent connectors shall be non-combustible and capable of withstanding flue gas temperatures as well as having sufficient strength to withstand physical damage likely to occur under the conditions of use. Vent connectors shall be securely supported.

3.6.3.2 Vent connectors shall not pass through walls or partitions constructed of combustible materials unless guarded at those points by ventilated metal thimbles, or suitable insulation and clearances, to keep surface temperatures of exposed combustible material below 160 F.

3.6.3.3 The vent connector should generally be the size of the flue collar or the size of the outlet of the draft hood. Where there is more than one flue outlet from one gas burning device the area of the connector should equal the combined areas of the outlets unless otherwise specified by the manufacturer.

Where separate gas equipment is served by a common vent the area of the connector should equal the combined area of the flue outlets which it serves.

3.6.4 Chimneys, Flues, and Stacks. Since industrial and commercial gas equipment covers a wide variety of sizes, temperatures, draft requirements and locations, no standard design specifications can be given for chimneys, flues, and stacks to properly dispose of products of combustion, except as provided in 3.6.1.1. The person or agency making and/or authorizing the installation should utilize the suggestions of equipment manufacturers and fuel engineers to obtain the most suitable chimney or flue design to satisfy the requirements of the particular installation.

3.7 Initial Operation

Under this caption appear suggested procedures to be followed in connection with initial operation of gas equipment, necessary adjustments, development of operating instructions, instruction of the operator in the safe and satisfactory use of the equipment, and required acceptance tests.

3.7.1 Agency Selected for Starting Up

3.7.1.1 The task of carrying out initial start-up, adjustments, and acceptance tests should be assigned by the person or agency authorizing the installation before any of these procedures take place. It should be assigned to a single responsible agency or person, hereafter called the "PRIMARY AGENCY." Full agreement concerning these procedures and methods should be reached in advance. (See Section 3.2.)

3.7.1.2 If a number of agencies has participated in the installation, primary authority should be assigned to the PRIMARY AGENCY. Other agencies involved in supplying or

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installing gas equipment should act under the supervision of the PRIMARY AGENCY.

3.7.1.3 Specified procedures should be performed by competent, qualified personnel.

3.7.2 New Gas Equipment Procedure. Before initially placing the gas equipment in operation, the PRIMARY AGENCY shall determine by physical check that all protective devices are connected and operative, the installation is in all respects capable of safe operation, the equipment has been purged in accordance with manufacturer's instructions, and that all interested persons have been notified. For satisfactory operation all mechanical and electrical devices should be checked at this time and determined to be operative.

3.7.2.1 Start-Up. Initial start-up should be conducted with full regard for special design features of the gas equipment, manufacturer's instructions, and applicable safety requirements. Unless purge cycle is provided, furnace or oven loading doors shall be opened before ignition is applied.

3.7.2.2 Operation. Installed protective devices shall, and other instruments and controls should, be checked under operating conditions as promptly as possible to determine that they are operating properly. Gas equipment shall be shut-down immediately if any defect is noted during initial start-up or operation. Defects shall be corrected before the equipment is again started up.

In shutting down equipment, manufacturer's instructions and applicable safety requirements shall be followed.

3.7.2.3 Adjustments. Adjustments to burners, pilots, ignition devices, protective devices, and controls should be made by, or under the supervision of the PRIMARY AGENCY, in accordance with manufacturer's instructions and applicable safety requirements.

3.7.3 Operating Instructions. Operating instructions should be supplied by gas equipment manufacturers covering equipment furnished by them. The PRIMARY AGENCY should assemble these instructions, develop any modifications found to be necessary, deliver them to the user, and instruct the operator in their use in order to insure safe and satisfactory operation of the equipment.

3.7.4 Acceptance Tests. The PRIMARY AGENCY should conduct acceptance tests if necessary to establish compliance with applicable codes or requirements of authorities having jurisdiction.

Upon proper notice by the PRIMARY AGENCY or the person authorizing the installation, the code or other jurisdictional authorities should promptly witness and state their findings as related to required acceptance tests.

3.7.5 Operating Personnel. An essential factor in securing satisfactory operation is the use of competent, well trained personnel to start up: To light; to adjust burners, mixers, fans, blowers, temperature controls, and protective devices; and to shut down.

3.8 Gas Equipment Maintenance

These suggestions are prepared for maintenance of gas equipment. Special types of furnaces demand special attention. A preventive maintenance program should be established and followed.

This program should include adherence to manufacturers' recommendations. In this program a minimum maintenance schedule should include inspection and action on the recommendations given in the following paragraphs. An adequate supply of repair parts should be maintained at all times.

3.8.1 Burners and Pilots. Burners and pilots should be kept clean and in proper operating condition.

Burner refractory parts should be examined at frequent regular intervals to be sure they are in good condition.

3.8.2 Flame Safeguard Equipment. When automatic flame safeguards are used a complete shut-down and restart should be made at frequent regular intervals to check the components for proper operation.

3.8.3 Other Safeguard Equipment

3.8.3.1 Accessory safeguard equipment such as manual reset valves with pressure or vacuum switches, high temperature limit switches, draft controls, shut-off valves, airflow switches, door switches, gas valves, etc., should be operated at regular intervals to insure proper functioning. If inoperative, they should be repaired or replaced.

3.8.3.2 When fire checks are installed in gas-air mixture piping to prevent flashbacks from traveling further upstream, the pressure loss across the fire checks should be measured at regular intervals. When excessive pressure loss is found, screens should be removed and cleaned. Water type backfire checks should be inspected and liquid level maintained.

3.8.3.3 All safety shut-off valves should be checked for leakage and proper operation at regular intervals.

3.8.4 Auxiliary Devices. Proper maintenance of auxiliary devices is a necessary part of the gas equipment maintenance. Maintenance instructions as supplied by the manufacturers of these devices should be followed.

Gas combustion equipment, including blowers, mechanical mixers, control valves, temperature control instruments, air valves, and air filters, should be kept clean and should be examined at regular intervals. Necessary repairs and replacements should be made promptly.

3.8.5 Regulators and Zero Governors. Regulator and zero governor vents and impulse or control piping and tubing should be kept clear. Improperly operating regulator valves should be cleaned, repaired, or replaced.

3.8.6 Piping. Proper maintenance of the gas piping system is a necessary part of the gas equipment maintenance. It is recommended that gas piping be inspected and tested for leakage at regular intervals in accordance with provisions in 2.10.3.

Air piping should be kept clean to prevent accumulation of dust, lint, and grease in air jets and valves.

Industrial Gas Nomenclature

EDITOR'S NOTE: This section was prepared from Information Letter No. 44, issued in 1951, by the AGA Industrial Gas Practices Committee, and was prepared by D. A. Campbell, Eclipse Fuel Engineering Company, Rockford, Illinois.

Gas engineers in different localities differ in their interpretation of terms applied to gas combustion systems and equipment.

The purpose of this *Information Letter* is to establish standard names for gas combustion systems, mixers, and burners.

It is hoped the terms and definitions will be accepted and used by the industry in all future bulletins, codes, and specifications.

As new methods of mixing gas and air for combustion are developed or processes of combustion are discovered, the accepted terms describing them should be added through revisions of this list.

A. Gas-Air Proportioning and Mixing Systems for Combustion

1. **Low Pressure Gas or "Atmospheric" System** (gas pressure less than ½ psig or 14-in. water column). A system using the momentum of a jet of low pressure gas to entrain from the atmosphere a portion of the air required for combustion.
2. **High Pressure Gas System** (gas pressure ½ psig or higher). A system using the momentum of a jet of high pressure gas to entrain from the atmosphere all, or nearly all, of the air required for combustion.
3. **Low Pressure Air System** (air pressure up to 5 psig). A system using the momentum of a jet of low pressure air to entrain gas to produce a combustible mixture.

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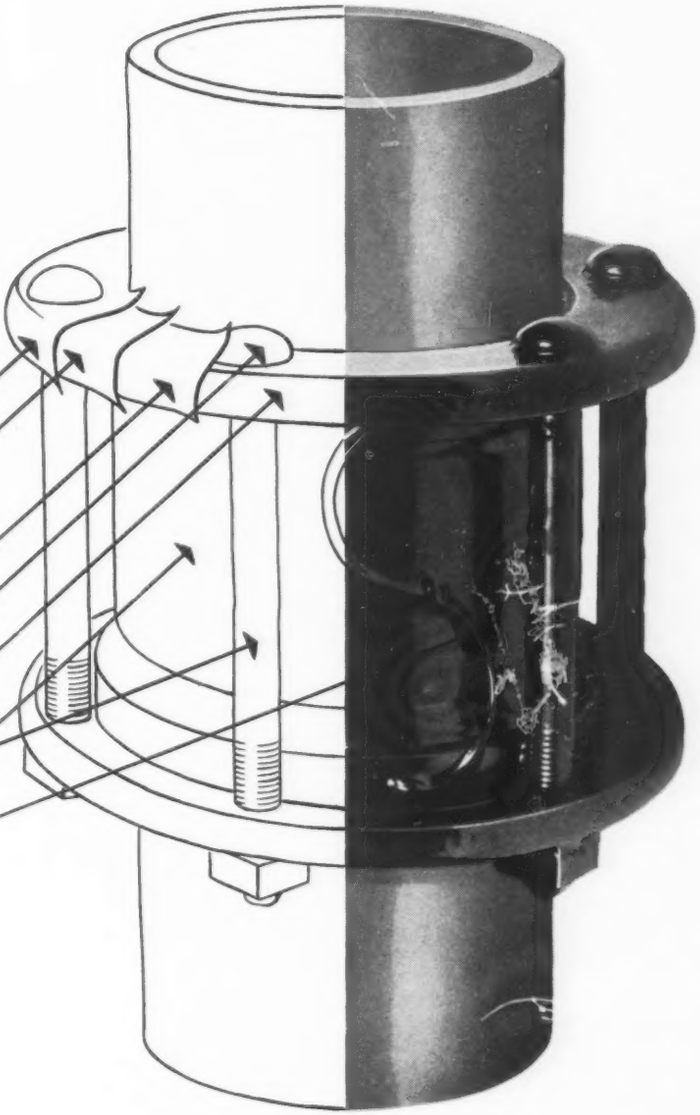
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4. **High Pressure Air System** (air pressure 5 psig or higher). A system using the momentum of a jet of high pressure air to entrain gas, or air and gas, to produce a combustible mixture.
5. **Suction System.** A system applying suction to a combustion chamber to draw in the air and/or gas necessary to produce the desired combustible mixture.
6. **Two Valve System.** A system using separate control of air and gas both of which are under pressure. The valves, controlling the air and gas flows, may or may not be interlocked.
7. **Mechanical System.** A system which proportions air and gas and mechanically compresses the mixture for combustion purposes. A central mixing unit may be used or individual appliances may each have its own mixer.

B. Mixers and Mixing Devices

1. **Mixer, General:** A device for mixing gas and air in any desired proportions.
2. **Manual Mixer:** A mixer that requires manual adjustments to maintain the desired air/gas ratio as rates of flow are changed.
3. **Automatic Mixer:** A mixer that automatically maintains within its rated capacity a substantially constant air/gas ratio at varying rates of flow. All types defined below can be designed to fit this classification.
4. **Gas Jet Mixer:** A mixer using the kinetic energy of a jet of gas issuing from an orifice to entrain all or part of the air required for combustion. Commonly used names of Gas Jet Mixers include: *Injector, Lojector, Venturi Mixer, Two Stage Mixer, Inspirator, Hijector, Tube Mixer, Atmospheric Mixer* and *Bunsen Mixer.*
5. **Air Jet Mixer:** A mixer using the kinetic energy of a stream of air issuing from an orifice to entrain the gas required for combustion. In some cases this type of mixer may be designed to entrain some of the air for combustion as well as the gas. Commonly used names of Air Jet Mixers include: *Low Pressure Inspirators, Aspirators, Flomixers, Mixjectors, Mixing Tees, Low Pressure Proportional Mixers, Vari Flame.*
6. **Mechanical Mixer:** A mixer using mechanical means to mix gas and air, neglecting entirely any kinetic energy in the gas and air, and compress the resultant mixture to a pressure suitable for delivery to its point of use. Mixers in this group utilize either a centrifugal fan or some other type of mechanical compressor with a proportioning device on its intake through which gas and air are drawn by the fan or compressor suction. The proportioning device may be automatic or require manual adjustment to maintain the desired air/gas ratio as rates of flow are changed. Names of Mechanical Mixers include: *Fan Mix, Industrial Carburetor, PreMix, Fantype Mixer, Combustion Controller, and Diluter.*

C. Burners

1. **Burner, General:** A device for the final release of air/gas, or oxygen/gas mixtures, or air and gas separately into the combustion zone.
   Industrial Gas Burners may be classed as atmospheric burners and blast or pressure burners.
2. **Atmospheric Burner:** A burner used in the Low Pressure Gas or "Atmospheric" system which required secondary air for complete combustion.
3. **Blast Burner:** A burner delivering a combustible mixture under pressure, normally above 0.3-in. wc to the combustion zone.
4. **Pressure Burner:** Same as Blast Burner.
5. **Single Port Burner:** A burner having only one discharge opening or port.
6. **Multiport Burner:** A burner having two or more separate discharge openings or ports. These ports may be either flush or raised.
7. **Line Burner:** A burner whose flame is a continuous "line" from one end to the other. Normally applied to a blast burner.
8. **Pipe Burner:** General term covering any type of atmospheric or blast burner made in the form of a tube or pipe with ports or tips spaced over its length.
9. **Ribbon Burner:** A burner having many small closely spaced ports usually made up by pressing corrugated metal ribbons in a slot or other shaped opening.
10. **Open Port Burner:** Any type of burner that fires across a gap into an opening in the furnace or combustion chamber wall and is not sealed into the wall. Burners of this type include: *Torch Burners, Tile Burners, Box Burners, Ventite Burners, Burmix Burners.*
11. **Tunnel Burner:** A burner sealed in the furnace wall in which combustion takes place mostly in a refractory tunnel or tuyere which is really part of the burner. Common names for Tunnel Burners include: *Walltite Burners, Impact Burners, Hyperblo Burners, Pyronic Burners, Refrak, Tunnel.*
12. **Flame Retaining Nozzle:** Any burner nozzle with built-in features to hold the flame at high mixture pressures. Names of Flame Retaining Nozzles include: *Sticktites, Ferrofix, Staylites, F. R. Nozzles.*
13. **Blast Tip:** A small metallic or ceramic burner nozzle so made that flames will not blow away from it, even with high mixture pressures.
14. **Nozzle Mixing Burner:** A burner in which the gas and air are kept separate until discharged from the burner into the combustion chamber or tunnel. Generally used with low pressure gas (up to ½ psig or 14-in. wc) and low pressure air (up to 5 psig).
15. **Proportional Mixing Burner:** An assembly which incorporates an automatic mixer and a burner as an integral unit. Trade names include: *L. P. Velocity, H. P. Velocity, Walltite.*
16. **Radiant Burner:** A burner designed to transfer a significant part of the combustion heat in the form of radiation from surfaces of various shapes which are usually of refractory material. Trade names include: *Red Ray, Duradiant, Burdette.*
17. **Luminous Flame Burner:** A burner which discharges nonturbulent parallel strata of air and gas to produce an extended flame of high luminosity.
18. **Ring Burner:** There are two types —
    (a) A form of atmospheric burner made with one or more concentric rings.
    (b) A form of burner used in firing boilers consisting of a perforated vertical gas ring with air admitted generally through the center of the ring. Combustion air may be supplied by natural, induced, or forced draft.
19. **Multijet Burner:** A form of burner which generally consists of gas manifolds with a large number of jets arranged to fire horizontally through openings in a vertical refractory plate. These openings are of various shapes — round, square, clover-leafed, etc. Combustion air may be supplied by natural, induced or forced draft. Complete assemblies combining burner, refractory plate, wind box, blower and controls are generally known as Forced Draft Boiler Burners. Trade names include: *Lo-Blast, Fan Mix, Flame King, Gas Pak.*
20. **Enclosed Combustion Burner:** A burner which confines the combustion in a small chamber or miniature furnace and only the high temperature completely combused gases, in the form of high velocity jets or streams, are used for heating. Trade names include: *Superheat, Zigzag.*
21. **Diaphragm Burner:** A burner which utilizes a porous refractory diaphragm as the port so that the combustion takes place over the entire area of this refractory diaphragm.
22. **Gas-Oil Burner:** A burner designed to burn gas and oil simultaneously.
23. **Dual Fuel Burner:** A burner designed to burn either gas or oil, but not both together.
24. **Combination Gas and Oil Burner:** A burner which can burn either gas or oil or both together.

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Gas Piping Installation

EDITOR'S NOTE: This section is extracted from ASA Z21.30-1959, *American Standard for the Installation of Gas Appliances and Gas Piping,* sponsored by the American Gas Association and approved by the American Standards Association on July 21, 1959. It is reproduced here by permission of A.G.A. This extract contains only sections 1 and 2, plus Appendix A (Work on Gas Supply Systems) and Appendix B (Example of Piping System in Accordance with 2.4.)

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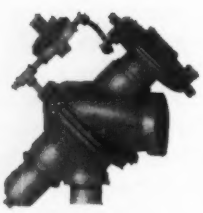

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PART I

1.1. Scope

This text represents basic standards governing the installation of gas appliances and gas piping. These standards apply only to low pressure (not in excess of ½ psi or 14 in. w. c.) gas piping systems extending from the outlet of the meter set assembly or the outlet of the service regulator when a meter is not provided, to the inlet connections of appliances, and the installation and operation of residential and commercial gas appliances supplied through such systems. They are intended to cover the design, fabrication, installation, tests and operation of such systems for fuel gases such as natural gas, manufactured gas, undiluted liquefied petroleum gases, liquefied petroleum gas-air mixtures or mixtures of any of these gases.

They are not intended to cover systems or portions of systems supplying equipment engineered, designed and installed for specific manufacturing, production processing and power generating applications, such as large and high pressure boilers, melting and treating furnaces, and production ovens. For piping in industrial plants, refer to the ASME Code for Pressure Piping, Section 2 of ASA B31.1-1955.

IN APPLYING THESE STANDARDS, REFERENCE SHOULD ALSO BE MADE TO THE MANUFACTURER'S INSTRUCTIONS, SERVING GAS SUPPLIER REGULATIONS, AND LOCAL BUILDING, HEATING, PLUMBING OR OTHER CODES IN EFFECT IN THE AREA IN WHICH THE INSTALLATION IS MADE.

As used in these standards:

The word *"approved"* means acceptable to the authority having jurisdiction.

The word *"piping"* refers to all pipe and tubing for any purpose, made of any material that is acceptable under these standards.

The word *"pipe"* refers only to rigid conduit of steel, iron, brass or copper that is acceptable under these standards.

The word *"tubing"* refers only to semi-rigid tubing of seamless copper, brass, steel or aluminum that is acceptable under these standards.

1.2. Qualified Installing Agency

Installation and replacement of gas piping or gas appliances and repair of gas appliances shall be performed only by a qualified installing agency. By the term *"qualified installing agency"* is meant any individual, firm, corporation, or company which either in person or through a representative is engaged in and is responsible for the installation or replacement of gas piping on the outlet side of the meter, or of the service regulator when a meter is not provided, or in the connection, installation or repair of gas appliances who is experienced in such work, familiar with all precautions required, and has complied with all the requirements of the authority having jurisdiction.

1.3. General Precautions

1.3.1. Turn Gas Off: All gas piping or gas appliance installation shall be performed with the gas turned off to eliminate hazards from leakage of gas.

1.3.2. Notification of Interrupted Service: It shall be the duty of the installing agency when the gas supply is to be turned off, to notify all affected consumers.

1.3.3. Before Turning Gas Off: Before turning off the gas to premises for the purpose of installation, repair, replacement or maintenance of gas piping or appliances, all burners shall be turned off. When two or more consumers are served from the same supply system, precautions shall be exercised to assure that only service to the proper consumer is turned off.

1.3.4. Checking for Gas Leaks: Soap and water solution, or other material acceptable for the purpose, shall be used in locating gas leakage. *Matches, candles, flame or other sources of ignition shall not be used for this purpose.*

1.3.5. Use of Lights: Artificial illumination used in connection with a search for gas leakage shall be restricted to electric hand flashlights (preferably of the safety type) or approved safety lamps. In searching for leaks, electric switches should not be operated. If electric lights are already turned on, they should not be turned off.

1.3.6. Working Alone: An individual shall not work alone in any situation where accepted working practice dictates that two or more men are necessary to perform the work safely.

1.3.7. Handling of Liquid from Drips: Liquid which is removed from a drip in existing gas piping shall be handled with proper precautions, and shall not be left on the consumer's premises.

1.3.8. No Smoking: When working on piping which contains or has contained gas, smoking shall not be permitted.

1.3.9. Handling Flammable Liquids: Flammable liquids used by the installer shall be handled with proper precautions and shall not be left within the premises

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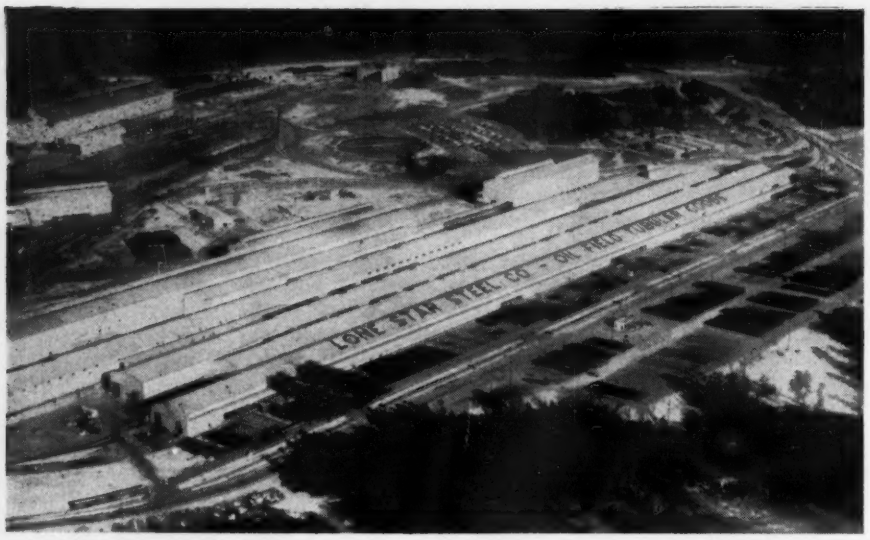

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1.3.10. Work Interruptions: When interruptions in work occur, the system shall be left in a safe and satisfactory condition.

PART II

Gas Piping Installation

2.1. Piping Plan

It is recommended that before proceeding with the installation of a gas piping system, a piping sketch or plan be prepared showing the proposed location of the piping as well as the size of different branches. Adequate consideration should be given to future demands, and provisions made for added gas service.

Before any final plans or specifications are completed, the serving gas supplier or the authority having jurisdiction should be consulted.

When an additional appliance is to be served through any present gas piping, capacity of the existing piping shall be checked for adequacy, and replaced with larger piping if necessary.

2.2. Provision for Meter Location

The meter location shall be such that the meter can be easily read and the connections are readily accessible for servicing. Location, space requirements, dimensions, and type of installation shall be acceptable to the serving gas supplier.

Gas piping at multiple meter installations shall be plainly marked by a metal tag or other permanent means attached by the installing agency, designating the building or the part of the building being supplied.

2.3. Interconnections

2.3.1. Interconnections Supplying Separate Consumers: When two or more meters, or two or more service regulators when meters are not provided, are installed on the same premises and supply separate consumers, the gas piping systems shall not be interconnected on the outlet side of the meters or service regulators.

2.3.2. Interconnections for Stand-By Fuels: When a supplementary gas for stand-by use is connected downstream from a meter or a service regulator when a meter is not provided, a suitable device to prevent backflow shall be installed. A three-way valve installed to admit the stand-by supply and at the same time shut off the regular supply may be used for this purpose.

2.4. Size of Piping to Gas Appliances

2.4.1. Size of Supply Piping for Gas Appliances: Gas piping shall be of such size and so installed as to provide a supply of gas sufficient to meet the maximum demand without undue loss of pressure between the meter, or service regulator when a meter is not provided, and the

appliance or appliances. The size of gas piping depends upon the following factors:

(a) Allowable loss in pressure from meter, or service regulator when a meter is not provided, to appliance.

(b) Maximum gas consumption to be provided.

(c) Length of piping and number of fittings.

(d) Specific gravity of the gas.

(e) Diversity factor.

2.4.2. Gas Consumption: The quantity of gas to be provided at each outlet shall be determined, whenever possible, directly from the manufacturer's Btu rating of the appliance which will be installed. In case the ratings of the appliances to be installed are not known, Table 1 is given to show the approximate consumption of average appliances of certain types in Btu per hour.

To obtain the cu ft per hr of gas required, divide the total Btu input of all appliances by the average Btu heating value per cu ft of the gas. The average Btu per cu ft of the gas in the area of the installation may be obtained from the serving gas supplier.

TABLE 1

Approximate Gas Input for Some Common Appliances

Appliance	Input Btu per hr. (Approx.)
Range, free standing, domestic	65,000
Built-In Oven or Broiler Unit, domestic	25,000
Built-In Top Unit, domestic	40,000
Water Heater, automatic storage—30 to 40 gal. tank	45,000
Water Heater, automatic storage—50 gal. tank	55,000
Water Heater, automatic instantaneous	
Capacity .. 2 gal. per min	142,800
Capacity .. 4 gal. per min	285,000
Capacity .. 6 gal. per min	428,400
Water Heater, domestic, circulating or side-arm	35,000
Refrigerator	3,000
Clothes Dryer, domestic	35,000

For specific appliances or appliances not shown above, the input should be determined from the manufacturer's rating.

2.4.3. Required Gas Piping Size: (a) Capacities in cu ft per hr of 0.60 specific gravity gas for different sizes and lengths of pipe are shown in Tables 2A and 2B. Table 2A is based upon a pressure drop of 0.3-in. w. c., whereas Table 2B is based upon a pressure drop of 0.5-in. w. c. In using these tables no allowance is necessary for an ordinary number of fittings. The serving gas supplier shall designate whether Table 2A or Table 2B shall be used.

Capacities of different sizes and lengths of semi-rigid tubing in thousands of Btu per hr with a pressure drop of 0.5-in. w. c. for undiluted liquefied petroleum gases are shown in Table 4. In using this Table, no allowance is necessary for an ordinary number of fittings.

TABLE 2A

Maximum Capacity of Pipe in Cubic Feet of Gas per Hour

(Based upon a Pressure Drop of 0.3-In. Water Column and 0.6 Specific Gravity Gas)

Length in Feet	Nominal Iron Pipe Size, Inches								
	½	¾	1	1¼	1½	2	2½	3	4
10	132	278	520	1050	1600	3050	480	8500	17,500
20	92	190	350	730	1100	2100	3300	5900	12,000
30	73	152	285	590	890	1650	2700	4700	9,700
40	63	130	245	500	760	1450	2300	4100	8,300
50	56	115	215	440	670	1270	2000	3600	7,400
60	50	105	195	400	610	1150	1850	3250	6,800
70	46	96	180	370	560	1050	1700	3000	6,200
80	43	90	170	350	530	990	1600	2800	5,800
90	40	84	160	320	490	930	1500	2600	5,400
100	38	79	150	305	460	870	1400	2500	5,100
125	34	72	130	275	410	780	1250	2200	4,500
150	31	64	120	250	380	710	1130	2000	4,100
175	28	59	110	225	350	650	1050	1850	3,800
200	26	55	100	210	320	610	980	1700	3,500

TABLE 2B

Maximum Capacity of Pipe in Cubic Feet of Gas per Hour

(Based upon a Pressure Drop of 0.5-In. Water Column and 0.6 Specific Gravity Gas)

Length in Feet	Nominal Iron Pipe Size, Inches								
	½	¾	1	1¼	1½	2	2½	3	4
10	175	360	680	1400	2100	3950	6300	11,000	23,000
20	120	250	465	950	1460	2750	4350	7,700	15,800
30	97	200	375	770	1180	2200	3520	6,250	12,800
40	82	170	320	660	990	1900	3000	5,300	10,900
50	73	151	285	580	900	1680	2650	4,750	9,700
60	66	138	260	530	810	1520	2400	4,300	8,800
70	61	125	240	490	750	1400	2250	3,900	8,100
80	57	118	220	460	690	1300	2050	3,700	7,500
90	53	110	205	430	650	1220	1950	3,450	7,200
100	50	103	195	400	620	1150	1850	3,250	6,700
125	44	93	175	360	550	1020	1650	2,950	6,000
150	40	84	160	325	500	950	1500	2,650	5,500
175	37	77	145	300	460	850	1370	2,450	5,000
200	35	72	135	280	430	800	1280	2,280	4,600

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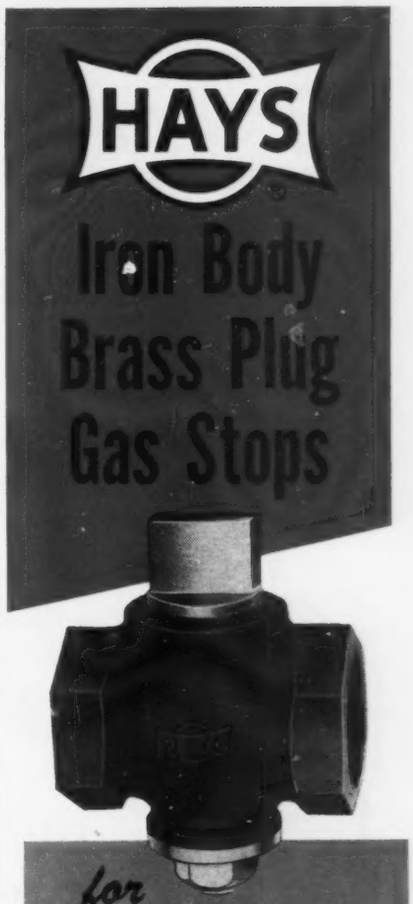

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(b) Gas piping systems that are to be supplied with gas of a sp gr of 0.70 or less, can be sized directly from Tables 2A and 2B unless the authority having jurisdiction specifies that a gravity factor be applied. When the sp gr of the gas is greater than 0.70, the gravity factor shall be applied.

Application of the gravity factor converts the figures given in Table 2A and 2B to capacities with another gas of different specific gravity. Such application is accomplished by multiplying the capacities given in Tables 2A and 2B by the multipliers shown in Table 3. In case the exact specific gravity does not appear in the Table, choose the next higher value specific gravity shown.

(c) To determine the size of each section of gas piping in a system within the range of Tables 2A, 2B or 4, proceed as follows: (A sample calculation is presented in Appendix B.)

(1) Calculate the gas demand in cu ft per hr of the appliance to be attached to each piping system outlet.

(2) Measure the length of piping from the gas meter or service regulator when a meter is not provided, to the most remote outlet in the building.

(3) In Table 2A, 2B, or 4, whichever is appropriate, select the distance, or the next longer distance if the Table does not give the exact length. This is the only distance used in determining the size of any section of gas piping. If the gravity factor is to be applied, the values in the selected column of Table 2A or 2B are multiplied by the appropriate multiplier from Table 3.

(4) Use this horizontal line to locate ALL gas demand figures for this particular system of piping.

(5) Starting at the most remote outlet, find in the horizontal line just selected the gas demand for that outlet. If the exact figure of demand is not shown, choose the next larger figure in the horizontal line.

(6) Above this demand figure, in Table 2A, 2B, or 4, will be found the correct size of gas piping.

(7) Proceed in a similar manner for each outlet and each section of gas piping. For each section of piping determine the total gas demand supplied by that section.

(d) For any gas piping system or special gas appliances, or for conditions other than those covered by Tables 2A, 2B or 4, such as longer runs or greater gas demands, the size of each gas piping system may be determined by standard engineer-

TABLE 3

Multipliers to Be Used Only With Tables 2A and 2B When Applying the Gravity Factor

Specific Gravity	Multiplier	Specific Gravity	Multiplier
.35	1.31	1.00	.78
.40	1.23	1.10	.74
.45	1.16	1.20	.71
.50	1.10	1.30	.68
.55	1.04	1.40	.66
.60	1.00	1.50	.63
.65	.96	1.60	.61
.70	.93	1.70	.59
.75	.90	1.80	.58
.80	.87	1.90	.56
.85	.84	2.00	.55
.90	.82	2.10	.54

TABLE 4

Capacity of Semi-Rigid Tubing of Different Outside Diameters and Lengths in Thousands of BTU per Hour of Undiluted Liquefied Petroleum Gases at a Pressure Drop of 0.50 Inch Water Column

Length of Tubing (Feet)	Outside Diameter (Inches)				
	3/8	1/2	5/8	3/4	7/8
10	39	92	199	329	501
20	26	62	131	216	346
30	21	50	107	181	277
40	19	41	90	145	233
50		37	79	131	198
60		35	72	121	187
70		31	67	112	164
80		29	62	104	155
90		27	59	95	146
100		26	55	90	138

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ing methods acceptable to the authority having jurisdiction and the serving gas supplier.

2.4.4. Diversity Factor: The diversity factor is an important factor in determining the correct gas piping size to be used in multiple family dwellings. It is dependent upon the number and kinds of gas appliances being installed. Consult the serving gas supplier or the authority having jurisdiction for the diversity factor to be used.

2.4.5. Additions to Existing Gas Piping: Additions to existing pipe in buildings shall conform to Table 2A or 2B, whichever is designated by the serving gas supplier. Additions to existing tubing in buildings, shall conform to Table 4. Existing gas piping shall be replaced by the proper size of pipe or tubing where necessary. In no case shall additions be made to existing pipe in buildings, which is smaller than permitted by Table 2A or 2B, or to existing tubing in buildings which is smaller than permitted by Table 4.

2.5 Acceptable Piping Materials

2.5.1. Piping Material for Utility Gases: Gas pipe shall be steel wrought-iron pipe complying with the American Standard for Wrought-Steel and Wrought-Iron Pipe, ASA B36.10-1950. Threaded copper or brass pipe in iron pipe sizes may be used with gases not corrosive to such materials. If acceptable to the serving gas supplier, piping installed outside a building to connect appliances located outside a building for use with utility gases may be of materials in accordance with either 2.5.1 or 2.5.2 with gases not corrosive to such material.

The connecting of steel or wrought-iron pipe by welding is permissible. Threaded pipe fittings (except stopcocks or valves) shall be malleable iron or steel when used with steel or wrought-iron pipe, and shall be copper or brass when used with copper or brass pipe. When approved by the authority having jurisdiction, special fittings may be used to connect steel or wrought-iron pipe. Cast iron fittings in sizes 4 in. and larger may be used to connect steel or wrought-iron pipe when approved by the authority having jurisdiction.

2.5.2. Piping Material for Liquified Petroleum Gases: Gas piping for use with undiluted liquefied petroleum gases shall be steel or wrought-iron pipe complying with American Standard for Wrought-Steel and Wrought-Iron Pipe, ASA B36.10-1950, and brass or copper pipe, or seamless copper, brass, steel or aluminum tubing. All pipe or tubing shall be suitable for a working pressure of not less than 125 psi. Copper tubing may be of the standard grade K or L, or equivalent,

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having a minimum wall thickness of 0.032-in. Aluminum tubing shall not be used in exterior locations or where it is in contact with masonry or plaster walls or insulation.

Piping joints may be screwed, flanged, welded, soldered or brazed with a material having a melting point exceeding 1000 F. Fittings shall be designed for a pressure of at least 125 psig. Cast-iron fittings shall be prohibited. Joints of seamless copper, brass, steel or nonferrous gas tubing shall be made by means of approved flared gas tubing fittings, or soldered or brazed with a material having a melting point exceeding 1000 F. Compression type tube fittings shall NOT be used.

2.5.3. Workmanship and Defects. Gas pipe or tubing, and fittings shall be clear and free from cutting burrs and defects in structure or threading and shall be thoroughly brushed, and chip and scale blown.

Defects in pipe or tubing or fittings shall not be repaired. When defective pipe, tubing or fittings are located in a system the defective material shall be replaced.

2.5.4. Pipe Coating: When in contact with material exerting a corrosive action, piping and fittings coated with a corrosion resisting material shall be used.

2.5.5. Use of Old Piping Material: Gas pipe, tubing, fittings, and valves removed from any existing installation shall not be again used until they have been thoroughly cleaned, inspected and ascertained to be equivalent to new material.

2.5.6. Joint Compounds: Joint compounds (pipe dope) shall be applied sparingly and only to the male threads of pipe joints. Such compounds shall be resistant to the action of liquefied petroleum gases.

2.6. Pipe Threads

2.6.1. Specifications for Pipe Threads: Pipe and fitting threads shall comply with the American Standard for Pipe Threads, ASA B2.1-1945, American Standard Taper Pipe Threads.

2.6.2. Damaged Threads: Pipe with threads which are stripped, chipped, corroded, or otherwise damaged shall not be used.

2.6.3. Number of Threads: Pipe shall be threaded in accordance with Table 5.

TABLE 5

Specifications for Threading Pipe

Iron Pipe Size (In.)	Approximate Length of Threaded Portion (Inches)	Approximate No. of Threads to be Cut
½	¾	10
¾	¾	10
1	⅞	10
1¼	1	11
1½	1	11
2	1	11
2½	1½	12
3	1½	12
4	1⅝	13

2.7. Concealed Piping in Buildings

2.7.1. Minimum Size: No gas pipe smaller than standard ½-in. iron pipe size shall be used in any concealed location.

2.7.2. Piping in Partitions: Concealed gas piping should be located in hollow rather than solid partitions. Tubing used with undiluted liquefied petroleum gases shall not be run inside walls or partitions unless protected against physical damage. This rule does not apply to tubing which passes through walls or partitions.

2.7.3. Piping in Floors: Gas piping in solid floors such as concrete shall be laid in channels in the floor, suitably covered to permit access to the piping with a minimum of damage to the building.

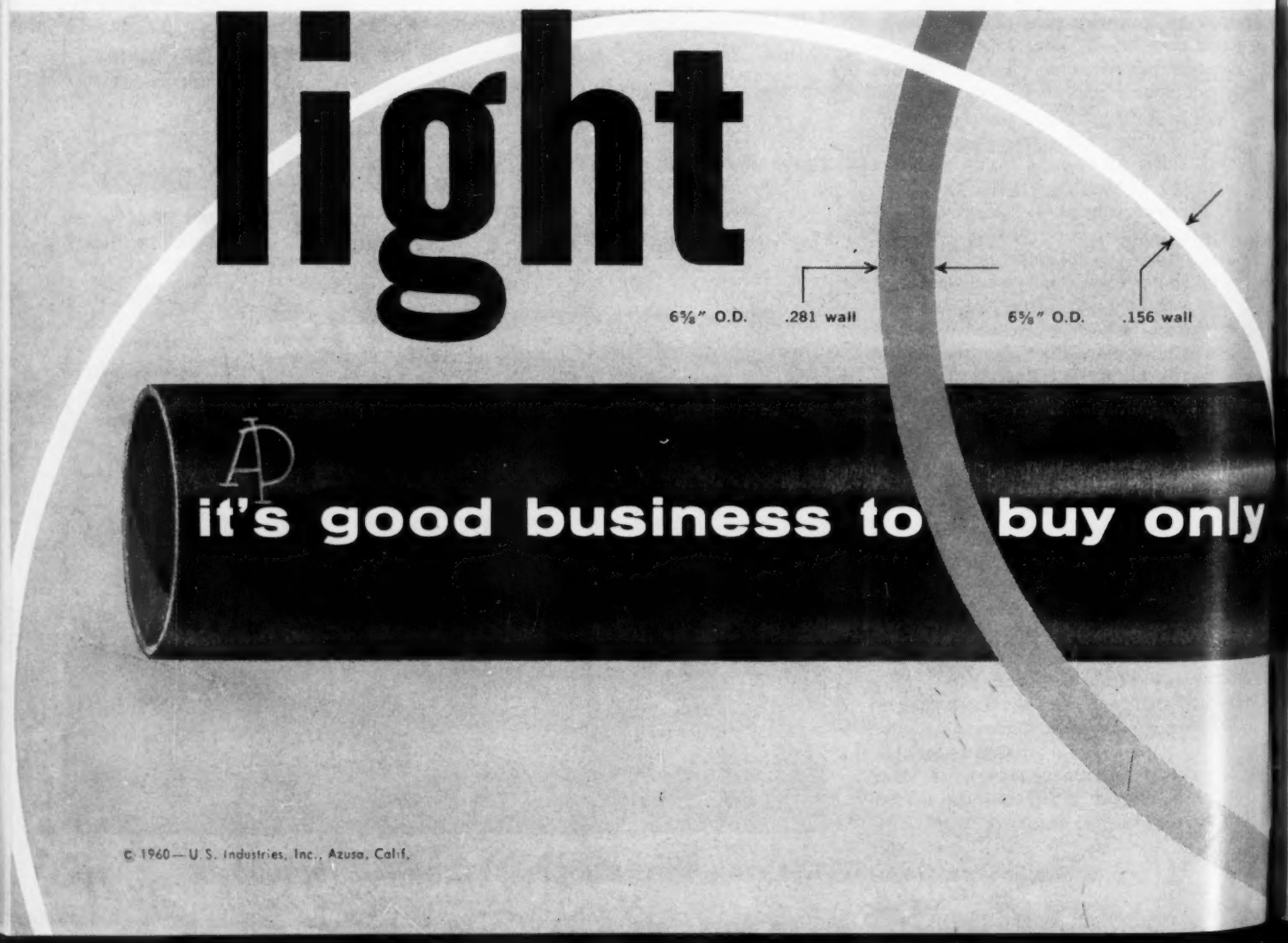
2.7.4. Connections in Original Installations: When installing gas piping which is to be concealed, unions, tubing, fittings, running threads, right and left couplings, bushings, and swing joints made by combinations of fittings shall not be used.

2.7.5. Reconnections: When necessary to insert fittings in gas pipe which has been installed in a concealed location, the pipe may be reconnected by use of a ground joint union with the nut center-punched to prevent loosening by vibration. Reconnection of tubing in a concealed location is prohibited.

2.8. Piping Underground

2.8.1. Protection Against Corrosion: Gas piping in contact with earth or other material which may corrode the piping, shall be protected against corrosion in an approved manner. Piping shall not be laid in contact with cinders.

Underground piping for manufactured gas shall be one size larger than that specified by Table 2A or Table 2B as designated by the serving gas supplier, but in no case less than 1¼-in.



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2.8.2. Piping Through Foundation Wall: Underground gas piping, when installed below grade through the outer foundation or basement wall of a building, shall be either encased in a sleeve or otherwise protected against corrosion. The piping or sleeve shall be sealed at the foundation or basement wall to prevent entry of gas or water.

2.8.3. Piping Underground Beneath Buildings: When installed underground beneath buildings, gas piping shall be encased in a conduit, which conduit shall extend into a normally usable and accessible portion of the building and, at the point where the conduit terminates in the building, the space between the conduit and the gas piping shall be sealed to prevent the possible entrance of any leakage. The conduit shall extend at least 4-in. outside the building, be vented above grade, and be installed in a way as to prohibit the entrance of water. The entire installation shall be such that the gas piping can be readily replaced without damage to the building.

2.9. Installation of Piping

Drips, grading and protection from freezing, as provided for in this section, shall apply only when other than dry gas is distributed and climatic conditions make such requirements necessary.

2.9.1. Building Structure: The building structure shall not be weakened by the installation of any gas piping. Before any beams or joists are cut or notched, special permission should be obtained from the authority having jurisdiction.

2.9.2. Gas Piping to Be Graded: All gas piping shall be graded not less than ¼-in. in 15 ft to prevent traps. All horizontal lines shall grade to risers and from the risers to the meter, or to service regu- to the appliance.

2.9.3. Piping Supports: Gas piping in buildings shall be supported with pipe hooks, metal straps, bands or hangers suitable for the size of piping, and of adequate strength and quality, and located at proper intervals so that the piping cannot be moved accidentally from the installed position. Gas piping shall not be supported by other piping.

Spacing of supports in gas piping installations shall not be greater than the following:

Size of Pipe (Inches)	(Feet)	Size of Tubing (Inch O.D.)	(Feet)
½	6	½	4
¾ or 1	8	⅝ or ¾	6
1¼ or larger (horizontal)	10	⅞ or 1	8
1¼ or larger (vertical)	every floor level		

2.9.4. Protect Against Freezing: Gas piping shall be protected against freezing temperatures. When piping must be exposed to wide ranges or sudden changes in temperatures, special care shall be taken to prevent stoppages.

2.9.5. Overhanging Rooms: Where there are overhanging kitchens or other rooms built beyond foundation walls, in which gas appliances are installed, care shall be taken to avoid placing the gas

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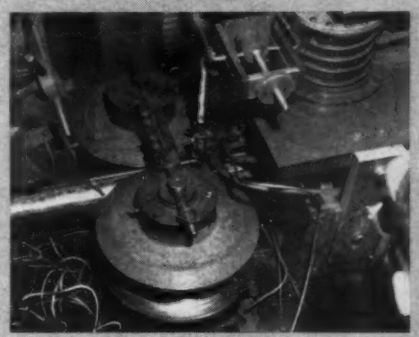

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piping where it will be exposed to low temperatures. (40 deg F or below for manufactured gas) or to extreme changes of temperatures. In such cases the gas piping shall be brought up inside the building proper and run around the sides of the room, in the most practical manner.

2.9.6. Do Not Bend Pipe: Gas pipe shall not be bent. Fittings shall be used when making turns in gas pipe.

2.9.7. Provide Drips Where Necessary: A drip shall be provided at any point in the line of pipe where condensate may collect. Where condensation is excessive, a drip should be provided at the outlet of the meter. This drip should be so installed as to constitute a trap wherein an accumulation of condensate will shut off the flow of gas before it will run back into the meter.

2.9.8. Location and Size of Drips: All drips shall be installed only in such locations that they will be readily accessible to permit cleaning or emptying. A drip shall not be located where the condensate is likely to freeze. The size of any drip used shall be determined by the capacity and the exposure of the gas piping which drains to it and in accordance with recommendations of the serving gas supplier.

2.9.9. Use Tee: If dirt or other foreign material is a problem, a tee fitting with the bottom outlet plugged or capped shall be used at the bottom of any pipe riser (see Figure 1).

2.9.10. Avoid Clothes Chutes, etc.: Gas piping inside any building shall not be run in or through an air duct, clothes chute, chimney or gas vent, ventilating duct, dumb waiter, or elevator shaft.

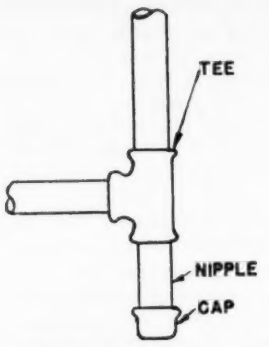

Fig. 1. Suggested Method of Installing Tee.

2.9.11. Cap All Outlets: Each outlet, including a valve or cock outlet, shall be securely closed gas-tight with a threaded plug or cap immediately after installation and shall be left closed until an appliance is connected thereto. Likewise, when an appliance is disconnected from an outlet and the outlet is not to be used again immediately, it shall be securely closed gas-tight. In no case shall the outlet be closed with tin caps, wooden plugs, corks, or by other improvised methods.

2.9.12. Location of Outlets: The unthreaded portion of gas piping outlets shall extend at least one inch through finished ceilings and walls, and when extending through floors shall be not less than 2 in. above them. The outlet fitting or the piping shall be securely fastened. Outlets shall not be placed behind doors. Outlets shall be far enough from floors, walls and ceilings to permit the use of proper wren-

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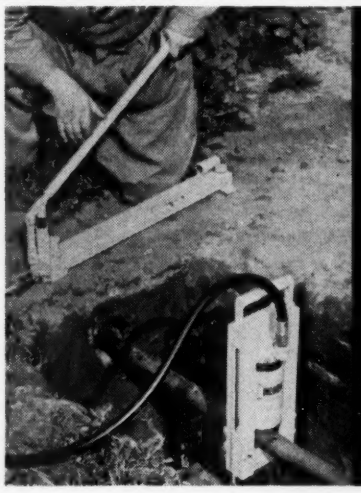

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ches without straining, bending or damaging the piping.

2.9.13. Prohibited Devices: No device shall be placed inside the gas piping or fittings that will reduce the cross-sectional area or otherwise obstruct the free flow of gas.

2.9.14. Branch Pipe Connection: All branch outlet pipes shall be taken from the top or sides of horizontal lines and not from the bottom. Where a branch outlet is placed on a main supply line before it is known what size of pipe will be connected to it, the outlet shall be of the same size as the line which supplies it.

2.9.15. Electrical Bonding and Grounding: A gas piping system within a building shall be electrically continuous and bonded to any grounding electrode, as defined by the National Electrical Code, NFPA No. 70 (ASA C1-1959).

Underground gas service piping shall not be used as a grounding electrode except when it is electrically continuous uncoated metallic piping and its use as a grounding electrode is acceptable both to the serving gas supplier and to the authority having jurisdiction, since gas piping systems are often constructed with insulating bushings or joints, or are of coated or nonmetallic piping.

2.10. Gas Shutoff Valves

2.10.1. Accessibility of Gas Valves: Main gas shut-off valves controlling several gas piping systems shall be placed an adequate distance from each other so they will be easily accessible for operation and shall be installed so as to be protected from physical damage. It is recommended that they be plainly marked with a metal tag attached by the installing agency so that the gas piping systems supplied through them can be readily identified. It is advisable to place a shutoff valve at every point where safety, convenience of operation, and maintenance demands.

2.10.2. Shutoff Valves for Multiple House Lines: In multiple tenant buildings supplied through a master meter or one service regulator when a meter is not provided, or where meters or service regulators are not readily accessible from the appliance location, an individual shutoff valve for each apartment or for each separate house line shall be provided at a convenient point of general accessibility.

2.11. Test of Piping for Tightness

Before any system of gas piping is finally put in service, it shall be carefully tested to assure that it is gas tight. Where any part of the system is to be enclosed or concealed, this test should precede the work of closing in. To test for tightness, the piping may be filled with the fuel gas, air or inert gas, but not with any other gas or liquid. OXYGEN SHALL NEVER BE USED.

2.11.1. Test Methods for Piping Systems:

(a) Before appliances are connected, piping systems shall stand a pressure of at least 6 in. mercury or 3 psig for a period of not less than 10 minutes without showing any drop in pressure. Pressure shall be measured with a mercury manometer or slope gage, or an equivalent device so

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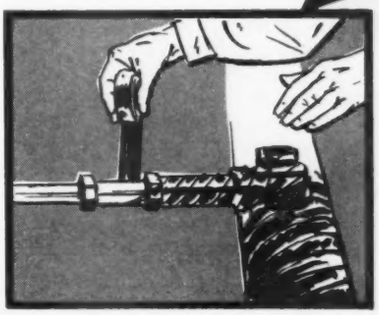
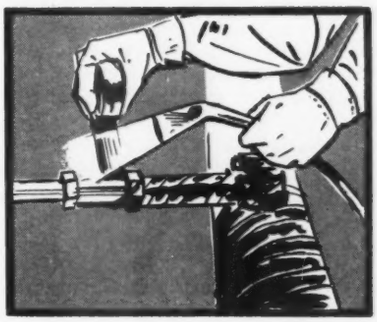


200 TAPE (cold application)

Protecto Wrap 200 Tape is a coal tar enamel-synthetic resin coating in tape form. A film of polyvinyl chloride is bonded to the outside of this tape. The addition of this group of synthetic resins to the enamel has upgraded the quality of the tar by increasing its ductility and also by increasing its water and oil repellent characteristics.

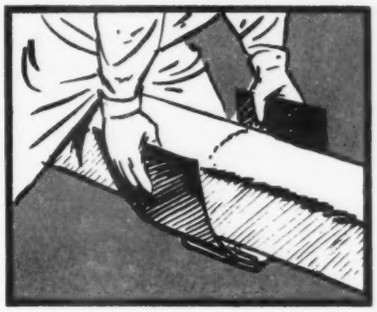
This PVC backing provides a tough surface for immediate backfilling and provides an exterior that is highly resistant to soil stress so there is little possibility of soil adhering to it.



STANDARD TAPE (torch application)

There are two kinds of Protecto Wrap Standard, Torch Applied Tapes: No. 110 Standard Coal Tar Tape and No. 120 Standard Asphalt Tape.

In each case, the base material (coal tar or asphalt) is saturated into a glass fabric that acts as a carrier and reinforcement. A paper separator insures even distribution of the coating as well as easy unwinding regardless of the temperature. They are used to form protective coatings for field joints on mill or yard coated pipe, fittings, couplings and other metal surfaces exposed to above or below ground corrosion.



FLOOD COATERS*

Protecto Wrap Flood Coaters consist of inorganic glass fiber impregnated with bituminous pipe coatings of coal tar or asphalt base, with an asbestos felt backing. They are wide enough to include the total bare cut-back where the pipe is welded together, and long enough to cover the circumference of the pipe, plus an additional length to provide over-lap on top of the pipe.

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calibrated as to read in increments of not greater than 0.1-psi. The source of pressure shall be isolated before the pressure tests are made.

(b) Systems for undiluted liquefied petroleum gases shall stand the pressure test in accordance with (a) above, or, when appliances are connected to the piping system, shall stand a pressure of not less than 10-in. w. c. for a period of not less than 10 minutes without showing any drop in pressure. Pressure shall be measured with a water manometer or an equivalent device so calibrated as to be read in increments of not greater than 1/10-in. w. c. The source of pressure shall be isolated before the pressure tests are made.

2.12. Leakage Check After Gas Turn On

2.12.1. Close All Gas Outlets: Before turning gas under pressure into any piping, all openings from which gas can escape shall be closed.

2.12.2. Check for Leakage: Immediately after turning gas into piping, the system shall be checked by one of the following methods to ascertain that no gas is escaping:

(a) *Checking for Leakage Using the Gas Meter:*

Immediately prior to the test it should be determined that the meter is in operating condition and has not been bypassed.

Checking for leakage can be done by carefully watching the test dial of the meter to determine whether gas is passing through the meter. To assist in observing any movement of the test hand, wet a small piece of paper and paste its edge directly over the center line of the hand as soon as the gas is turned on. Allow five minutes for a one-half foot dial and proportionally longer for a larger dial in checking for gas flow. This observation should be made with the test hand on the upstroke.

In case careful observation of the test hand for a sufficient length of time reveals no movement, the piping shall be purged and a small gas burner turned on and lighted and the hand of the test dial again observed. If the dial hand moves (as it should), it will show that the meter is operating properly. If the test hand does not move or register flow of gas through the meter to the small burner, it is certain that the meter is defective and the gas should be shut off and the serving gas supplier notified.

(b) *Checking for Leakage Not Using a Meter:*

This can be done by attaching to an appliance orifice a manometer or equivalent device calibrated so that it can be read in increments of 0.1-in. w. c., and momentarily turning on the gas supply and observing the gaging device for pressure drop with the gas supply shut off. No discernible drop in pressure shall occur during a period of 10 minutes.

(c) *When Leakage Is Indicated:*

If the meter test hand moves, or a pressure drop on the gage is noted, all appliances or outlets supplied through the system shall be examined to see if they are shut off and do not leak. If they are found tight there is a leak in the piping

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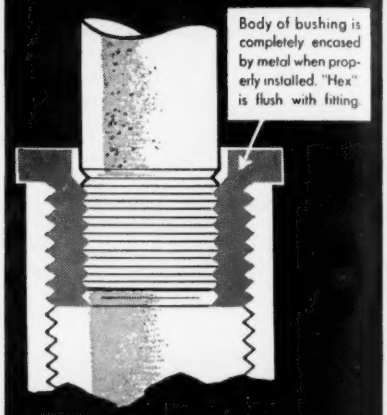

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system. The gas supply shall be shut off until the necessary repairs have been made, after which the test specified in (a) or (b) shall be repeated.

2.13. Purging

2.13.1. Purging All Gas Piping: After piping has been checked, all piping receiving gas shall be fully purged. A suggested method for purging the gas piping to an appliance is to disconnect the pilot piping at the outlet of the pilot valve. Under no circumstances shall piping be purged into the combustion chamber of an appliance.

2.13.2. Light Pilots: After the gas piping has been sufficiently purged, all appliances shall be purged and the pilots lighted. The installing agency shall assure itself that all piping and appliances are fully purged before leaving the premises.

APPENDIX A

Work on Gas Supply System

This appendix applies only to work on gas supply systems ahead of the outlet of the meter set assembly, or of the service regulator when a meter is not provided.

Serving Gas Supplier's Main

No person, unless in the employ of, or having permission from, the serving gas supplier, shall open or make connections with a gas main.

Service Gas Piping

No person, unless in the employ of, or having permission from, the serving gas supplier, shall repair, alter, open or make connections to the service gas piping, or do any other work on the parts of the gas supply system up to the meter set assembly or the service regulator when a meter is not provided.

Meter or Service Regulator When a Meter is Not Provided

No person, unless in the employ of or having permission from the serving gas supplier, shall disconnect the inlet of the gas meter or service regulator when a meter is not provided, nor move such meter or regulator. A gas fitter or plumber may disconnect the outlet of such a meter or regulator from the house piping only when necessary. He shall remake the joint at the meter or service regulator outlet when a meter is not provided, carefully replacing all insulating fittings or insulating parts of such fittings, and shall leave the gas turned off at the meter or regulator unless the serving gas supplier's rules require or allow deviation from this procedure.

Notify Servicing Gas Supplier of Any Repairs Needed

In case any work done by a gas fitter or plumber discloses the need for repairs or alterations on any part of the gas supply system, the serving gas supplier shall be notified promptly of this fact.

Notify Servicing Gas Supplier of Any Leaks

If gas is leaking from any part of the gas supply system, a gas fitter or plumber not in the employ of the serving gas supplier may make necessary repairs and shall promptly notify the serving gas supplier.

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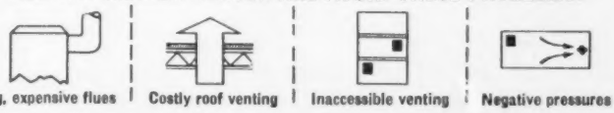

Big, expensive flues | Costly roof venting | Inaccessible venting | Negative pressures

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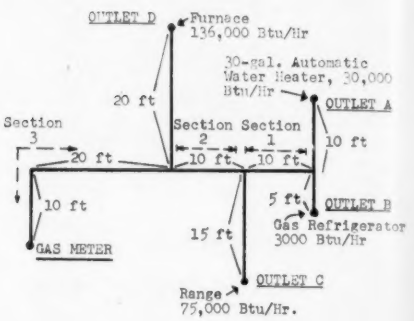
APPENDIX B

Example of Piping System Design Sized in Accordance with 2.4:

Determine the required pipe size of each section and outlet of the piping system shown in Exhibit 1, with a designated pressure drop of 0.50-in. w. c. Gas to be used has 0.65 specific gravity and a heating value of 1000 Btu per cu ft.



Solution:

(1) Maximum gas demand for outlet A: Consumption (rating plate input or Table 1 if necessary) divided by Btu of gas = cu ft per hr.

$$\frac{\text{30,000 Btu per hr rating}}{\text{1000 Btu per cu ft}} = 30 \text{ cu ft per hr}$$

Maximum gas demand for outlet B:

$$\frac{\text{Consumption}}{\text{Btu of gas}} = \frac{3000}{1000} = 3 \text{ cu ft per hr}$$

Maximum Gas demand for outlet C:

$$\frac{\text{Consumption}}{\text{Btu of gas}} = \frac{75{,}000}{1000} = 75 \text{ cu ft per hr}$$

Maximum gas demand for outlet D:

$$\frac{\text{Consumption}}{\text{Btu of gas}} = \frac{136{,}000}{1{,}000} = 136 \text{ cu ft per hr}$$

(2) The length of pipe from the gas meter to the most remote outlet (A) is 60 ft. This is the only distance used.

(3) Using the column marked 60 ft in Table 2B (provided this is the Table designated for use by the serving gas supplier):

Outlet A, supplying 30 cfh, requires ½-in. pipe.
Outlet B, supplying 3 cfh, requires ½-in. pipe.
Section 1, supplying outlets A and B, or 33 cfh, requires ½-in. pipe.
Outlet C, supplying 75 cfh, requires ¾-in. pipe.
Section 2, supplying outlets A, B and C, or 108 cfh, requires ¾-in. pipe.
Outlet D, supplying 136 cfh, requires ¾-in. pipe.
Section 3 supplying outlets A, B, C and D, or 244 cfh, requires 1-in. pipe.

(4) If the gravity factor (see 2.4.3-b) is applied to this example, the values in the column marked 60 ft of Table 2B would be multiplied by the multiplier (0.96) from Table 3, and the resulting cu ft per hr values would be used to size the piping.

* * *